MICHAEL CHESTER & PARTNERS Consulting Civil and Structural Engineers
8 Hale Lane London NW7 3NX tel 020 8959 9119 fax 020 8959 9662 mail@michaelchester.co.uk

Our Ref: 15094 July 2016

66 FITZJOHN'S AVENUE, LONDON NW3

RESPONSE TO QUERIES RAISED IN CAMPBELL REITH'S BASEMENT IMPACT ASSESSMENT AUDIT

INTRODUCTION:

Michael Chester & Partners prepared a structural Basement Impact Assessment (BIA) to accompany a planning application for the above site by Webb Architects. The application included the demolition of an existing semi-detached property followed by the construction of a new semi-detached building with basement.

Campbell Reith act on behalf of London Borough of Camden and they have prepared an Audit Report of the BIA. The following addresses the queries raised by Campbell Reith in the Audit Tracker contained within Appendix 2 of their report. The queries are reproduced for ease of reference.

QUERIES RAISED IN AUDIT TRACKER REPORT:

1. **All geotechnical data i.e laboratory testing, interpretations, derived geotechnical parameters for design etc. to be provided. Further ground monitoring to be carried out.**

   No laboratory testing was carried out, only the insitu testing noted on the borehole logs included within the structural BIA. This is because the engineering properties of the Claygate Beds and London Clay are well known to piling contractors who regularly work within London. Also, our experience is that, on small project like this, piling contractors prefer insitu tests to determine pile design parameters because they find they more accurately reflect the ground conditions than do laboratory tests (samples are often poorly taken) plus the fact that there are inadequate economies of scale to make the savings on pile construction that laboratory tests might allow on much larger projects.

   Additional ground water monitoring has been carried out and the results are considered further in the response to the Audit Tracker by the Hydrological Engineer, SLR Consulting, contained under separate cover.

2. **Are there any basements in adjacent properties and/or what are foundation types, depths etc?**

   There is a half depth basement at No.64 Fitzjohn's Avenue. Foundations details are not known but the building is a traditionally built Victorian structure so they have conservatively been assumed to be shallow corbelled brickwork. The next closest property is 12m distant from the site. It is not known whether this building has a basement but it is sufficiently far away that it is, in any case, not relevant to this development in purely structural terms.

3. **Is there a tunnel beneath the access strip adjacent to No.64 Fitzjohn's Avenue and will it be affected by the works or trafficking?**

   Desk studies have revealed no evidence of a tunnel or culvert running across the strip of land adjacent to No.64 though some sources do indicate an old upper tributary of the Tyburn to the east of No.64.

   Before work commences on site the contractor will be required to carry out a ground radar survey to investigate this further. They will also be required to provide a temporary road base that will span over any anticipated soft spots. At this stage this is assumed to take the form of a thick reinforced concrete slab built off a DoT subbase.

4. Is site access road supported by the wall of No.64 Fitzjohn's Avenue? Is it structurally able to support proposed construction traffic loads?

As above, there is a half depth basement to the full footprint of No.64 Fitzjohn's Avenue so, yes, the flank wall will be required to support some traffic loads from the access road. The access road is narrow, however, being only 2.6m wide at its pinch point, so vehicular access will be limited. Material deliveries during construction will, therefore, in any case, have to be made in small loads.

The road is currently used by cars to access the properties at the rear and there is no evidence that this is having or has had a detrimental effect on the wall. The wall in question is 450mm thick at its base and it is preloaded at the very least by 13m of brickwork. MCP have carried out some preliminary calculations to assess the strength of the wall and these are contained within Appendix A. They concur with the visual evidence and show that the wall and its foundations are capable of withstanding a surcharge of 2.5kN/m^2 whilst maintaining reactions within the middle third of the foundation (factor of safety against overturning is, therefore, in excess of 3) and without excessive brick bearing stresses.

As above, the contractor will in any case be required to provide a road base that will span over possible soft spots. This will have the benefit of distributing wheel and axial loads more evenly along the length of the wall and across the width of the access road and will help to mitigate any adverse effects of the traffic.

5. Further review of potential ground movement/building damage assessment needed, in particular heave due to the 4.5m excavation and installation of piles in form clay.

Pile calculations have been received from Southern Geotechnical Design Ltd and a geotechnical report on the heave aspects has been received from Donaldson Associates. Both are contained within Appendices B & C below and both concur with the original BIA, confirming that if ground movements occur beyond the site boundary anticipated damage would fall within categories 0 or 1, negligible to very slight.

Southern Geotechnical Design's calculations consider temporary propping during the works at just below existing ground level to allow the capping beam to be formed along the heads of the piles and permanent props at new basement slab and ground floor slab levels. The sequence of construction assumes that the temporary prop will be in place before bulk excavation commences and that the basement slab will be formed as soon as excavation reaches the appropriate depth. The calculations predict that the maximum settlement depth will be 4mm at 3m from the face of the new piled wall, tailing off to zero at 14m distance from the piled wall. No.64 Fitzjohn's Avenue is approximately 3m from the piled wall; the possible movement gives a strain of 0.036% corresponding to a damage assessment of category 0. No.14 Arkenside Road is 10m from the piled wall; predicted settlements at this distance are in the order of 1.5mm with a similar overall strain anticipated.

Donaldson Associates have considered the above along with the heave movements due to the release of overburden following the excavation. They have predicted vertical movements of between 4mm and 7mm at the face of No.64 Fitzjohn's Avenue and horizontal movements of between 6mm and 9mm resulting in a strain of 0.05%. This corresponds to a damage assessment on the border between category 0 and category 1. They have also predicted vertical movements of between 0mm and 4mm and horizontal movements of between 1mm and 5mm for No.14 Arkenside Road resulting again in a strain of 0.005%. Because of its distance from the excavation Donaldson Associates have concluded that there is a very low risk of damage to No.14 Arkenside Road and propose no further assessment but they recommend monitoring of No.62/64 Fitzjohn's Avenue.

6. Confirmation of impact of removal of Silver Birch tree required.

Silver Birches are classed by the National House Building Council's (NHBC) guidelines for building near trees as low water demand trees. The height of the Silver Birch in question is between about 10m and 12m and it is 3.4m from the face of No.64 Fitzjohn's Avenue. Based on this, the NHBC Standards Part 4.2 Chart 1 indicates that foundations deeper than 1.35m will be beyond the zone of influence of the roots. The difference in ground levels between where the Silver Birch is growing and the basement is 1.6m. The foundations are, therefore, clearly deeper than required by the NHBC guidelines so the removal of this tree will not affect No.64 Fitzjohn's Avenue. There are no other buildings within the zone of influence of the tree.

7. A monitoring regime for adjacent buildings/infrastructure is required, including development of trigger and action levels.

Donaldson Associates have recommended monitoring of No.62/64 Fitzjohn's Avenue during the course of the works. Given the very small movements anticipated consideration is to be given to the use of an "intelligent" data logging system which will provide greater accuracy than traditional tell-tales or demountable gauges and will provide more detailed information around particular movement "events" if they occur. A green, amber, red traffic light system of trigger and action levels will be developed in conjunction with the Party Wall Surveyors.

8. Indicative structural calculations and construction sequence required showing principles of design and propping, and consideration of dewatering.

Drawing number 15094/SK02revA by MCP (Appendix D) and pile calculations by Southern Geotechnical Design Ltd (Appendix B) describe the sequence of construction and principles of the design and propping. In summary this is as follows –

a) Erect a hoarding around the site and demolish the existing building.
b) Install a secant piled wall around the perimeter of the proposed basement, sealed in to the London Clay.
c) Pump ground water out from within the footprint of the proposed basement.
d) Construct a capping beam to tie the heads of the piles and install horizontal props to restrain the head of the piled wall.
e) Excavate within the piles to new basement level. Cast new basement slab and the new permanent retaining walls all round the excavation.
f) Cast the ground floor level slab.
g) Remove temporary props when ground floor level slab is fully cured.
h) Complete construction of superstructure.

In terms of dewatering, as set out in the original BIA, it is proposed to install a secant piled wall sealed off in to the London Clay. This will prevent water entering the excavation from the side through the piled wall and from below, thus allowing the water within the basement footprint to be pumped out completely prior to excavation. As no water is able to enter the excavation during the work, no fines are lost from the soils beyond the piled perimeter of the site thus eliminating the associated effects of soil consolidation on the surrounding ground and buildings.

MICHAEL CHESTER & PARTNERS Consulting Civil and Structural Engineers
8 Hale Lane London NW7 3NX tel 020 8959 9119 fax 020 8959 9662 mail@michaelchester.co.uk

APPENDIX A

66 FITZJOHN'S AVENUE, LONDON NW3

PRELIMINARY CALCULATIONS FOR FLANK WALL OF No.64 FITZJOHN'S AVENUE

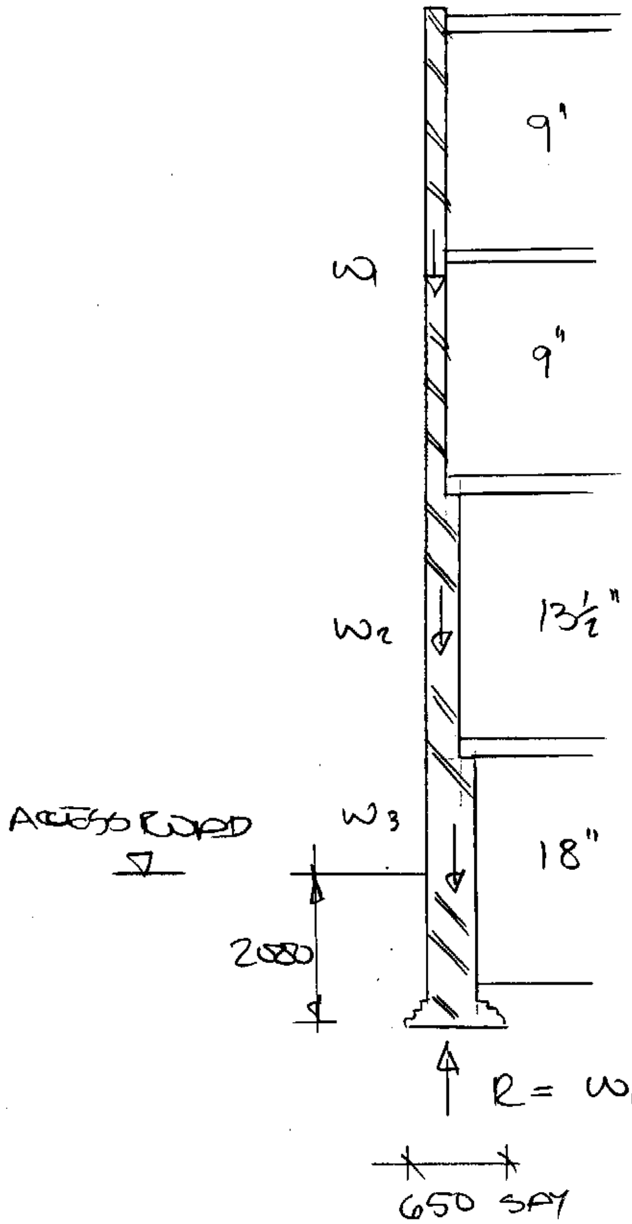
MICHAEL CHESTER & PARTNERS
Consulting Civil & Structural Engineers

8 Hale Lane London NW7 3NX tel 020 8959 9119 fax 020 8959 9662

Date	Job No	Sheet No	Rev
JUN 16	15094	PW01	
Eng: DM			

Project: 66 FITZJOHN'S AVENUE LONDON NW3

FLANK WALL OF Nº 64 FITZJOHN'S ROAD



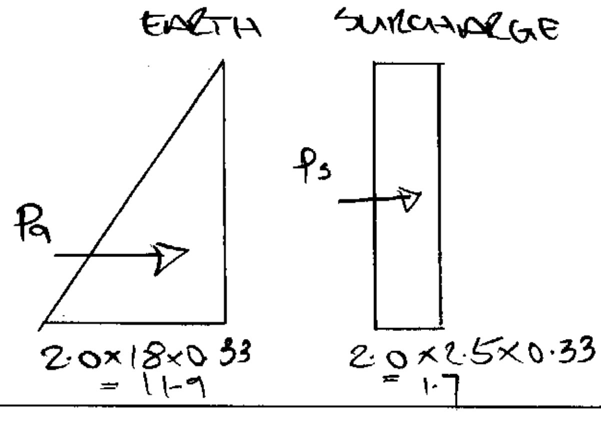
$W_1 = 6.5 \times 5.0 = 32.5\,kN$

$W_2 = 3.5 \times 7.6 = 26.6\,kN$

$W_3 = 3.5 \times 10.2 = 35.7\,kN$.

$R = W_1 + W_2 + W_3 = 95\,kN$.

OVERTURNING.



$P_a = \frac{1}{2} \times 2.0 \times 11.9 = 11.9\,kN$

$P_s = 2.0 \times 1.7 = 3.4\,kN$

MICHAEL CHESTER & PARTNERS Consulting Civil & Structural Engineers	Date JUN 16	Job No	Sheet No	Rev
8 Hale Lane London NW7 3NX tel 020 8959 9119 fax 020 8959 9662	Eng TDM	15094	RW02	
	Project 66 FITZJOHN'S AVENUE LONDON NW3			

OVERTURNING MOMENT -

$$M_{ov} = (11.9 \times 2.0/3) + (3.4 \times 2.0/2) = 11.3 kNm$$

ECCENTRICITY OF LOADING -

$$95\bar{y} = (32.5 \times 443) + (26.6 \times 385) + (35.7 \times 325) - 11.3 \times 10^3$$

$$\bar{y} = 263$$

$$e = 325 - 263 = 62$$ ∴ WITHIN MIDDLE THIRD

THEREFORE FACTOR OF SAFETY AGAINST OVERTURNING GREATER THAN 3

INCREASES IN BEARING PRESSURES ARE VERY SHORT TERM AND WILL HAVE NO APPRECIABLE EFFECT ON THE FOUNDATION.

BRICK STRESSES AT BASE OF WALL -

$$\sigma_b = \frac{95 \times 10^3}{1000 \times 450} \pm \frac{6 \times 95 \times 10^3 \times 62}{1000 \times 450^2}$$

$$0.21 \pm 0.18$$

$$MAX = 0.39 \; N/mm^2$$
$$MIN = 0.03 \; N/mm^2$$
} OK.

APPENDIX B

66 FITZJOHN'S AVENUE, LONDON NW3

PILING CALCULATIONS BY SOUTHERN GEOTECHNICAL DESIGNS LTD

STRUCTURAL ENGINEERING CALCULATIONS

PRELIMINARY DESIGN OF SECANT BORED PILE RETAINING WALL

AT

66, FITZJOHNS AVENUE

LONDON

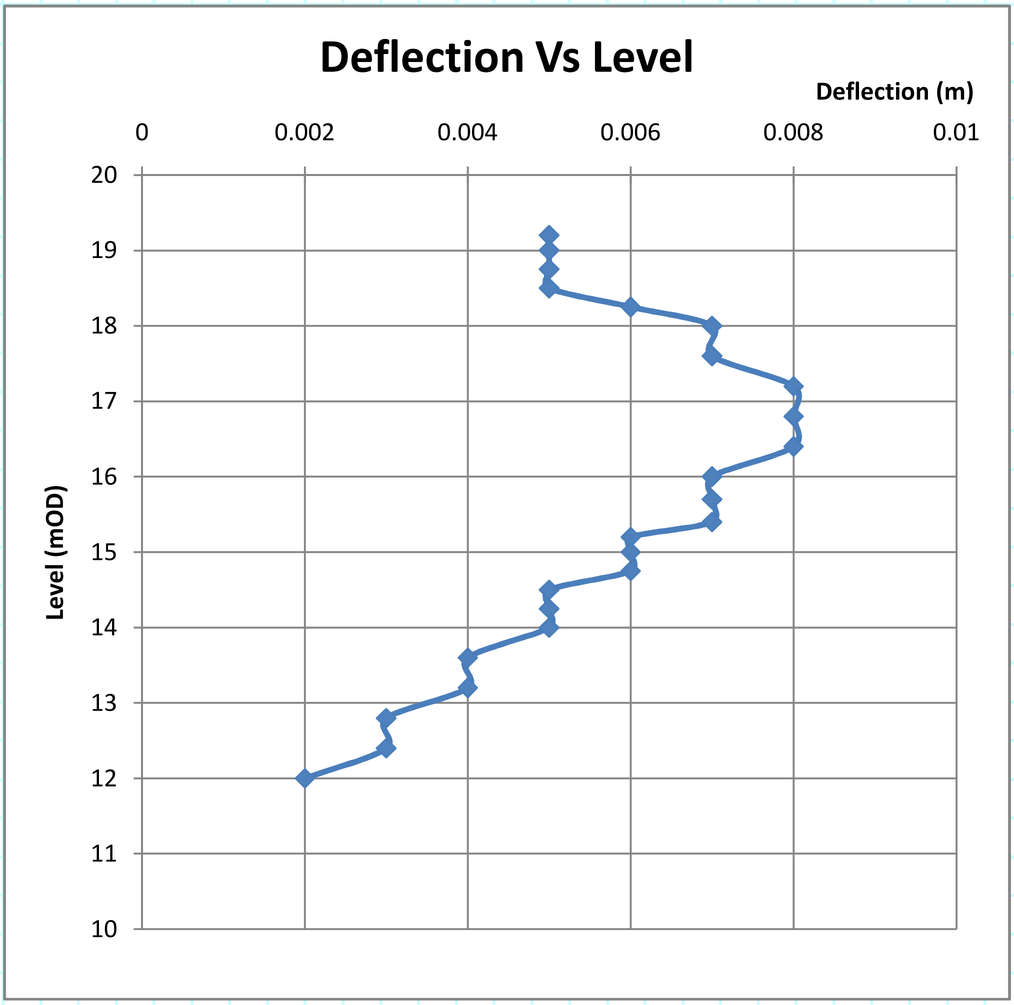
NW3 5LT

ISSUE	DATE	STATUS	REVISION DESCRIPTION	PAGES
00	21 May 2016		Initial Design	

Executive Summary

Based on the wall being 350 mm diameter piles at
550 mm centres

The anticipated deflected shape of the wall is:



Based on figure 2.16 in CIRIA C580

For this wall	δ0 =	5	mm	Thus anticipated settlment at wall =	2.5	mm
	δmax =	8	mm	Thus maximum ground settlement =	4.0	mm
		at 3m depth		at 3m from wall		

Maximum distance from wall of any vertical movement is likely to be 14.0m

Contents

1 Introduction

CP Plus Ltd has commissioned Southern Geotechnical Design Limited to carry out the preliminary design for the secant pile walls that are required for to retain the ground at 66, Fitzjohns Avenue, London NW3 5LT. The wall will be constructed as a propped bottom up excavation. Ground level is at 19.3mOD formation is at 15.0mOD (allowing for 485mm of slab construction).

1.1 Reference Documents

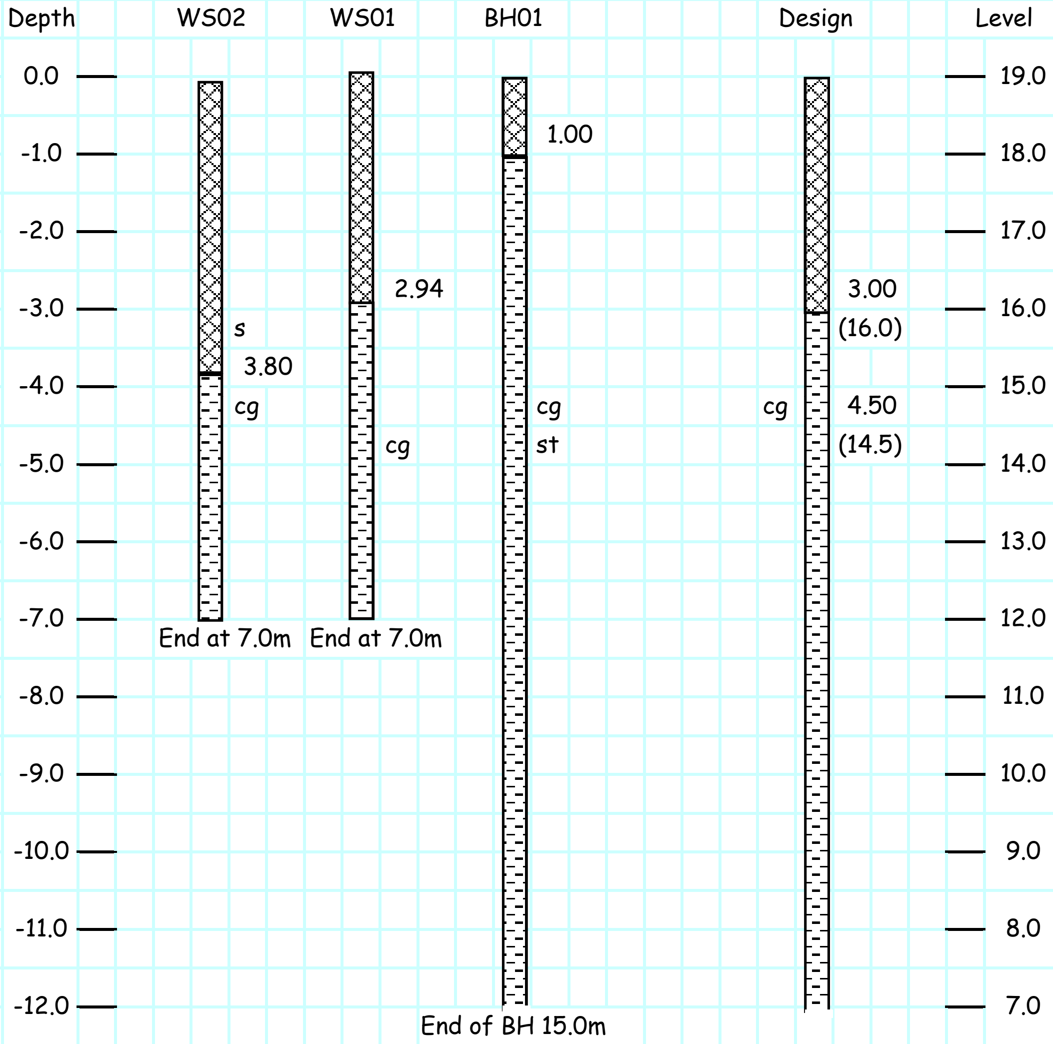
Specification	ICE SPERW
Site Investigation	SLR Hydrology Report For Basement Impact Assessment
Drawings	Numbered 15094/SK01 "Typical Section Through Basement"
Michael Chester	Numbered 15094/SK02 revision A "Assumed Sequence of Construction".
	Numbered 15094/SK03 "Section Indicating Surcharge Loading"
Web Architects	Numbered 1169.01.01(-) "Location Plan".
	Numbered 1169.01.11(-) "Proposed Front Elevation".
	Numbered 1169.01.12(-) "Proposed Basement Plan".
	Numbered 1169.01.13(-) "Proposed Ground Floor Plan".
	Numbered 1169.01.14(-) "Proposed First Floor Plan".
	Numbered 1169.01.15(-) "Proposed Second Floor Plan".
	Numbered 1169.01.14(-) "Proposed Roof Plan".
MJH Surveyors	Numbered 0160 03 "Front Elevation No 66".
	Numbered 0163 01 "Site Plan".
	Numbered 0163 01 "Roof Plan".
	Numbered 0163 04 "Rear Elevation No 66".
	Numbered 0163 05 "Side Elevation No 66".
	Numbered 0163 06 "Side Elevation No 66".
	Numbered 0163 07 "Side Elevation".
	Numbered 0163 08 "Rear Elevation No 12".
Codes, Standards & References:	
	BS EN 1997-1: 2004 Eurocode 7: Geotechnical Design - Part 1: General Rules
	UK National Annex to Eurocode 7: Geotechnical Design - Part 1: General Rules.
	CIRIA C580 London 2003 Embedded Retaining Walls - Guidance For Economic Design
	BS EN 1992-1-1: 2004 Eurocode 2: Design of Concrete Structures - Part 1-1: General Rules and Rules for Buildings
	UK National Annex to Eurocode 2: Design of Concrete Structures - Part 1-1: General Rules and Rules for Buildings
	"Pile design and construction practice", M J Tomlinson, 4th ed, 1994.

Charts for the design of circular columns to Eurocodes, IstructE Manual for the design of concrete building structures to Eurocode 2.

2 Ground Conditions

2.1 Strata Profile

The ground investigation shows the following strata:



Key: Made Ground   Stiff slighty sandy London Clay

The 'design' borehole is therefore taken as:

From	PPL	to	16.00	mOD	Made Ground
From	16.00	to	14.50	mOD	Claygate Beds - sandy Clay
From	14.50	to	Toe	mOD	Stiff slighty sandy London Clay

Ground water was struck in BH1 at 5.0m depth, however the level given on drawing 15094 SK01 of 16.4mOD is taken as more realistic

2.2 Soil Parameters

Moderately conservative soil parameters are required for the wall calculations. Some of these parameters will be factored for various of the analyses as detailed below:

	On Su	c'	tan φ'	E
For SLS analysis	1.0	1.0	1.0	1.0
For Com 2 analysis	1.40	1.25	1.25	1.0

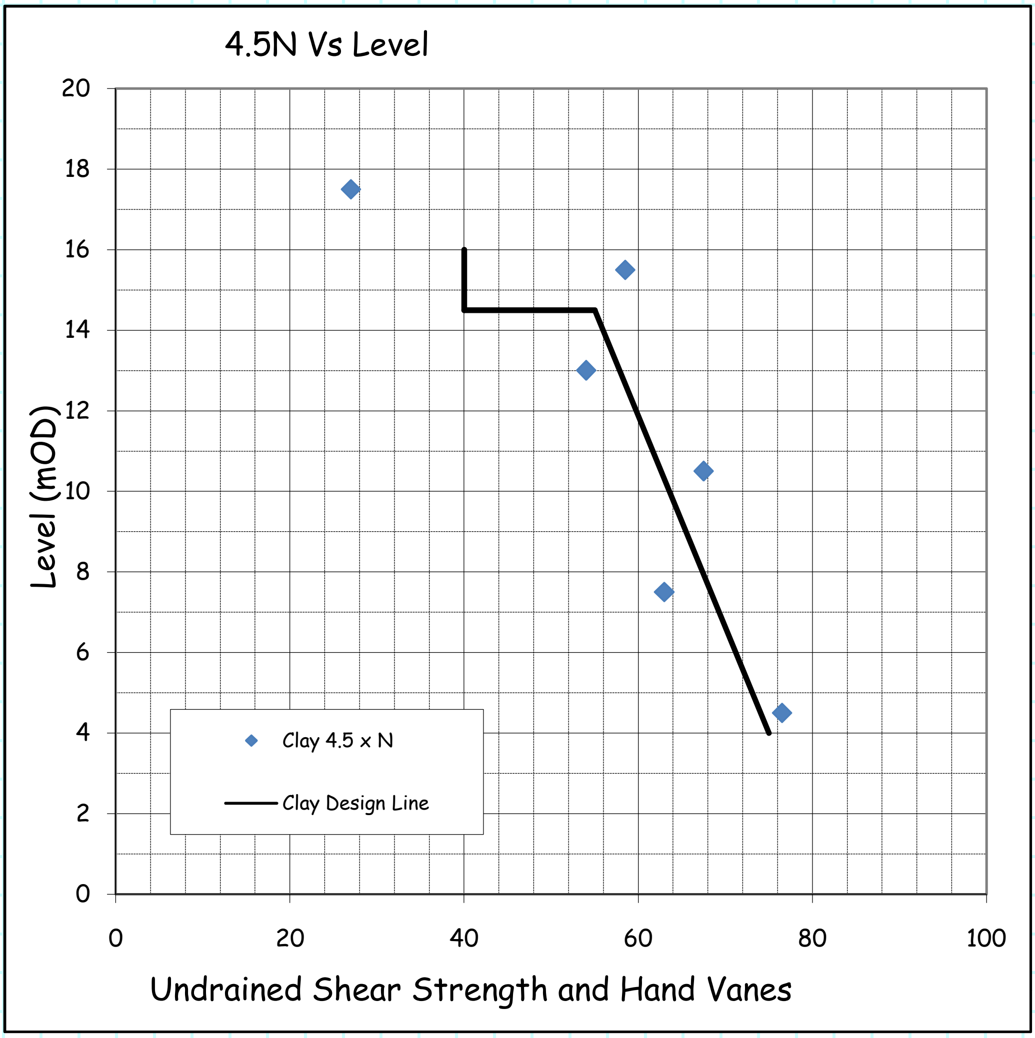
WALL FRICTION

For the bored pile walls there will be friction between the soil and the piles, this acts to reduce the active limit of soil pressure and increase the passive.

However when axial compression load is applied to the wall, it settles slightly, in this case since the piles are moving in the same direction as the active wedge, the active wall friction is taken as zero. The passive wall friction however remains the same.

The active wall friction will not be set to zero since there is no vertical load applied to the piled walls.

The undrained shear strength (triaxials and hand vane) plot versus depth is presented below.



MADE GROUND / OVERBURDEN

Bulk density, γb = 18 kN/m^3
Soil type Cohesionless
Angle of friction, φ' = 30 °
Effective cohesion c' = 0 kN/m^2
Earth pressure coefficients, at rest, ko = 0.50
Elastic Modulus E = 10000 $kN/m^2/m$

CLAYGATE BEDS

From 16mOD to 14.5mOD - Firm sandy clay - Claygate.
Bulk density, γb = 20 kN/m^3
Soil type Cohesive Undrained
Undrained Shear Strength Cu = 40 kN/m^2
allow softening 20 % Cud = 32 kN/m^2
Elastic Modulus, Eu / Cu = 800 based on cantilever and large strain
Eu = 32 MN/m^2
Drained parameters
Drained Shear Strength c' = 0 kN/m^2
Angle of friction, φ' = 22 °
Earth pressure coefficients, ko = 0.625
Elastic Modulus, E' = 0.7 Eu
E' = 22.4 MN/m^2

LONDON CLAY

From 14.5mOD to Toe - Stiff slightly sandy Clay - London Clay.
Bulk density, γb = 20 kN/m^3
Soil type Cohesive Undrained
Undrained Shear Strength Cu = 55 + 1.9 z kN/m^2
allow softening 20 % Cud = 44 + 1.52 z kN/m^2
Elastic Modulus, Eu / Cu = 800 based on cantilever and large strain
Eu = 44 + 1.52 z MN/m^2
Drained parameters
Drained Shear Strength c' = 0 kN/m^2
Angle of friction, φ' = 24 °
Earth pressure coefficients, ko = 0.593
Elastic Modulus, E' = 0.7 Eu
E' = 30.8 + 1.07 z MN/m^2

2.3 Groundwater

Ground water was struck in BH1 at 5.0m depth, however the level given on drawing 15094 SK01 of 16.4mOD is taken as more realistic

3 Basis of Design

3.1 General

The design is based on the following:

- The soil and properties used are correct for the whole site.
- The strata used are correct for the whole site.
- The retained geometry and construction sequences are as given in Appendix A
- Surcharge on the retained soil is as detailed in section 6.3.

3.2 Bearing Capacity

There are no vertical loads on the wall, other than those exerted by the ties.

3.3 Lateral Loads

The forces induced in the piled wall and the props will be calculated using the Wallap computer programme.

3.4 Structural Parameters

3.4.1 Wall Piles

Type CFA

Grout fcu 35 N/mm^2 28 day characteristic cube strength

fck 28 N/mm^2 28 day characteristic cylinder strength

Reinforcement fy 500 N/mm^2

Young's Modulus of pile: instantaneous Ecm = $22 \times \{(fck + 8) / 10\} / 1.5\}^{0.3}$

= 32.3 GN/m^2

short term Ecs = 0.7 Eci

= 22.6 GN/m^2

long term Ecs = 0.5 Eci

= 16.2 GN/m^2

Diameter 350 mm

Spacing 550 mm

Second Moment of area $= \pi d^4 / 64s$

1.34E-03 m^4 / m

Thus wall stiffness is:

Short term 30290 kN/m^2

Long term 21640 kN/m^2

3.4.2 Struts

Strut details are given below:

Type	Centre Level (mOD)	Spacing (m)	Cross Section (m^2)	Young's Modulus (kN/m^2)	Free Length (m)	Angle (°)	Pre-Stress (kN)	Tension Allowed?
Temp	18.5	5	0.02	2.0E+08	5	0	0.0	No
Perm GF	19.2	1	0.4	2.0E+07	5	0	0.0	No
Perm B1	15.2	1	0.4	2.0E+07	5	0	0.0	No

4 Factors of Safety

4.1 Axial Load - Compression

The factor of safety for the vertical load will be 3.0

4.2 Axial Load - Tension

The factor if safety for the tensile tie load will be 3.0

4.3 Lateral and Moment Loads

The forces within the piles in the wall have been calculated using EC7. An SLS and a single ULS (Design approach 1 Combination 2) analyses have been carried out with the soil parameters factored as detailed in section 2.2.
The forces generated by these analyses will be further factored for the structural analysis of the pile. These factors are as follows:

For ULS use factor of	1.00
For SLS use factor of	1.35

The pile structural analysis will be carried out with the maxima from these two results.

4.4 Strut Loads

The strut loads are taken from the ULS and SLS wallap analyses and are then factored for the strut design using the same factors detailed for structural analysis above.

5 Basis of Design

5.1 Negative Skin Friction

Given the site details it is extremely unlikely that the soil will induce negative skin friction on the piles, therefore no allowance is made for any.

5.2 Heave Forces

There is no likelihood of heave being induced in the wall piles.

5.3 Pile Spacing

The piles will be designed on the basis of the nominal 550mm spacing.

5.4 Pile Tolerances

The piles will be installed to the standard piling tolerances, that is 1:75 verticality and +or- 75mm position. (Note that the positional tolerance increases if cut off level is below platform level at 1:75).

6 Analysis

6.1 Wall Description

The retaining wall is required to allow for the short term excavation and construction of the new structure. In the long term there will be a lining wall which will eventually be required to carry the hydrostatic pressures, not-with-standing this the piled wall is also designed for these loads.

The Engineer's sketch indicates that the piled wall will be installed, and, following a minimal excavation (say 1.0m) will be trimmed and a capping beam cast. A temporary strut will be installed and excavation continued to formation level. The base slab and roof slabs will then be cast and the temporary strut removed.

6.2 Construction Sequence for wall

The construction sequence is detailed below.

1. Prepare platform at 19.0mOD (estimated).
2. Apply existing surcharges
3. Re zero walls to represent as is situation.
4. Apply general surcharges.
5. Excavate 18.0mOD to allow cap to be built.
6. Install temporary prop at 18.5mOD
7. Excavate to 15.0mOD (Allow 0.35m unplanned excavation in ULS Com 2)
8. Fill to 15.48mOD on excavated side.
9. Install B1 slab to prop wall at 15.2mOD
10. Remove temporary prop at 18.5mOD
11. Allow soil and wall to relax to long term parameters
12. Allow long term flood conditions

6.3 Surcharge Loads

The surcharges used are detailed below:

1	Building dead	allow	115	kN/m	applied at	18.0	mOD	
		over	1.0	m width	at	4.0	m from wall	
2	Building live	allow	17	kN/m²	applied at	18.0	mOD	
		over	1.0	m width	at	4.0	m from wall	
3	General	allow	10	kN/m²	applied at	19.0	mOD	
		at	0.0	m from the wall over		4.0	m width	

6.4 Lateral and Moment Loads

There are no lateral or moment loads.

6.5 Wallap output

The Wallap input and output is presented in Appendix B

Wall		Moment (kNm/m)	Shear (kN/m)	Toe (mOD)	Defl (mm)	Struts (kN/m) Temp 18.5	Perm 19.2	Perm 15.2
All	Com 1	50	70			40	35	85
	Com 2	65	74	12.0		55	45	100
	SLS	50	50		8	40	35	40
	Des	68	95	12.0	8	55	47	115

Note Strut loads are kN per m run of wall at 90 degrees to wall

6.6 Reinforcement

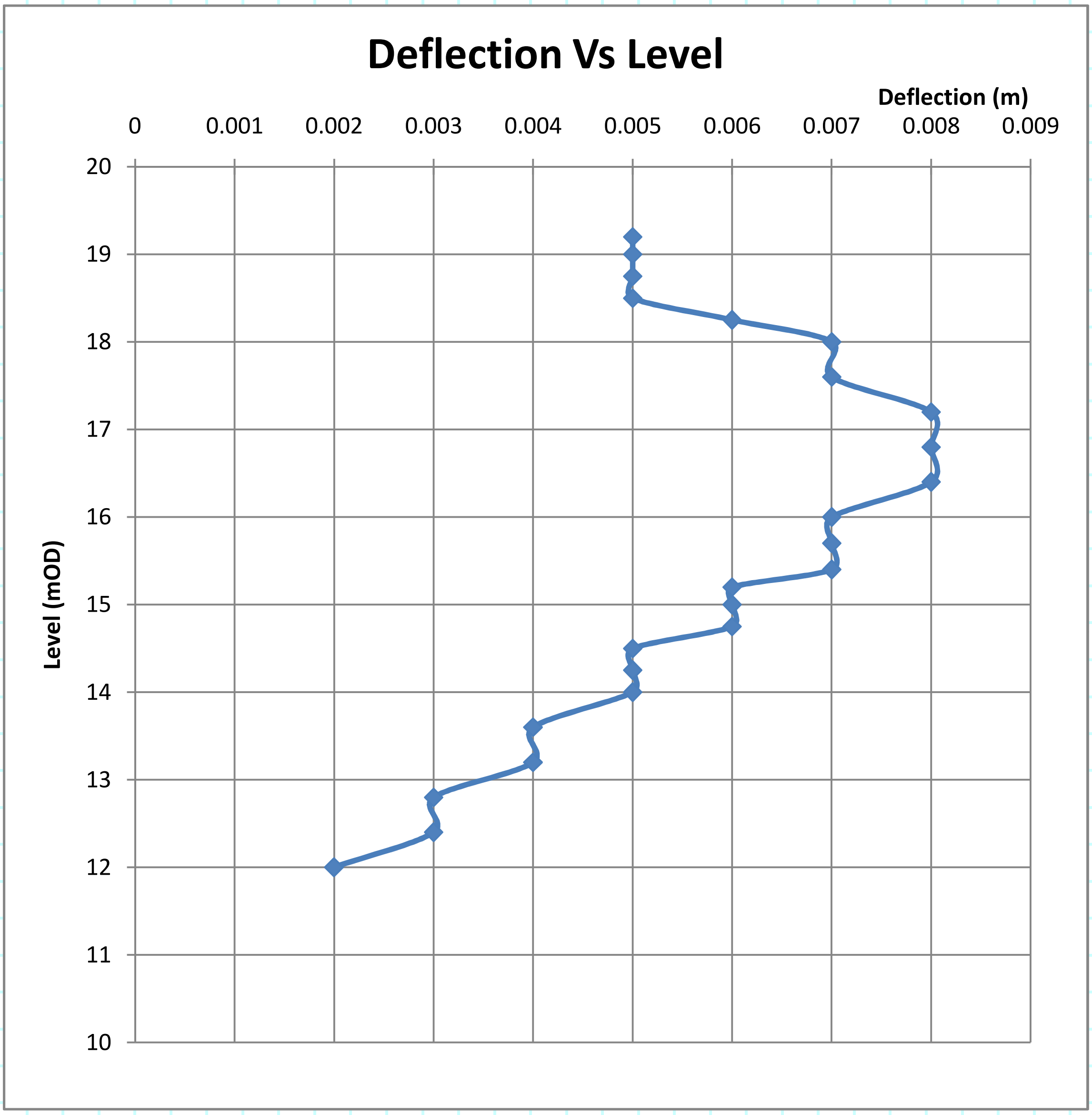
Reinforcement is designed using the I Struct E circular column design charts, conservatively based on the uncased pile section.
Standard sheets are used, these are presented in Appendix C.

6.7 Wall Vertical Capacity

No loads 54.70 mOD

6.8 Defelction

The anticipated maximum deflection is given in section 6.5 above.
The anticipated deflected shape of the wall is presented in graphical format overleaf.



Based on figure 2.16 in CIRIA C580

For this wall	δ0 =	5 mm	Thus anticipated settlment at wall =	2.5	mm
	δmax =	8 mm	Thus maximum ground settlement =	4.0	mm
		at 3m depth	at 3m from wall		

Maximum distance from wall of any vertical movement is likely to be 14.0m

APPENDIX A - Construction Sequences

Refer to Michael Chester Drawing 15094/SK02 revision A

Stages

1	Prepare platform at 19.0mOD (estimated).
2	Apply existing surcharges
3	Re zero walls to represent as is situation.
4	Apply general surcharges. 0
5	Excavate 18.0mOD to allow cap to be built.
6	Install temporary prop at 18.5mOD
7	Excavate to 15.0mOD (Allow 0.35m unplanned excavation in ULS Com 2)
8	Fill to 15.48mOD on excavated side.
9	Install B1 slab to prop wall at 15.2mOD
10	Remove temporary prop at 18.5mOD
11	Allow soil and wall to relax to long term parameters
12	Allow long term flood conditions

APPENDIX B – WALLAP INPUT / OUTPUT – COM 1

```
SOUTHERN GEOTECHNICAL DESIGN                            | Sheet No.
Program: WALLAP  Version 6.05  Revision A45.B58.R49     | Job No.   C0745
                             Licensed from GEOSOLVE     | Made by :    MP
Data filename/Run ID: Com 1                             |
66 Fitzjohns Avenue, London NW3 5LT                     | Date:23-05-2016
Com 1                                                   | Checked :
-----------------------------------------------------------------------------
                                                     Units: kN,m
```

INPUT DATA

SOIL PROFILE

Stratum no.	Elevation of top of stratum	Soil types: Active side	Soil types: Passive side
1	19.00	1 Made Ground	1 Made Ground
2	16.00	2 Claygate Undr	2 Claygate Undr
3	15.00	2 Claygate Undr	3 Claygate To soft
4	14.50	4 London Clay Undr	4 London Clay Undr

SOIL PROPERTIES (Unfactored SLS soil strengths)

-- Soil type -- No.	Description (Datum elev.)	Bulk density kN/m3	Young's Modulus Eh,kN/m2 (dEh/dy)	At rest coeff. Ko (dKo/dy)	Consol state. NC/OC (Nu)	Active limit Ka (Kac)	Passive limit Kp (Kpc)	Cohesion kN/m2 (dc/dy)
1	Made Ground	18.00	10000	0.500	OC	0.333	4.369	
					(0.200)	(0.000)	(0.000)	
2	Claygate Undr	20.00	32000	1.000	OC	1.000	1.000	32.00u
					(0.490)	(2.000)	(2.000)	
3	Claygate To soft	20.00	32000	1.000	OC	1.000	1.000	32.00u
					(0.490)	(2.000)	(2.000)	
4	London Cl..	20.00	44000	1.000	OC	1.000	1.000	44.00u
	(14.50)		(1520)		(0.490)	(2.000)	(2.390)	(1.520)
5	Claygate ..	20.00	1	1.000	OC	1.000	1.000	1.000u
	(15.00)		(64000)		(0.490)	(2.000)	(2.000)	(64.00)
6	Claygate Dr	20.00	22400	1.000	OC	0.455	2.198	0.0d
					(0.150)	(1.349)	(2.965)	
7	London Cl..	20.00	30800	1.000	OC	0.422	3.077	0.0d
	(14.50)		(1070)		(0.150)	(1.299)	(4.665)	

Additional soil parameters associated with Ka and Kp

------- Soil type ------- No.	Description	--- parameters for Ka --- Soil friction angle	Wall adhesion coeff.	Back-fill angle	--- parameters for Kp --- Soil friction angle	Wall adhesion coeff.	Back-fill angle
1	Made Ground	30.00	0.000	0.00	30.00	0.500	0.00
2	Claygate Undr	0.00	0.000	0.00	0.00	0.000	0.00
3	Claygate To soft	0.00	0.000	0.00	0.00	0.000	0.00
4	London Clay Undr	0.00	0.000	0.00	0.00	0.500	0.00
5	Claygate Soft	0.00	0.000	0.00	0.00	0.000	0.00
6	Claygate Dr	22.00	0.000	0.00	22.00	0.000	0.00
7	London Clay LT	24.00	0.000	0.00	24.00	0.500	0.00

GROUND WATER CONDITIONS

Density of water = 10.00 kN/m3

	Active side	Passive side
Initial water table elevation	16.40	16.40

Automatic water pressure balancing at toe of wall : No

Water press. profile no.	Active side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	Passive side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	
1	1	16.40	16.40	0.0	1	15.00	15.00	0.0	MC
					2	13.00	16.40	34.0	
2	1	16.40	16.40	0.0	1	14.65	14.65	0.0	WC
					2	12.60	16.40	38.0	
3	1	16.40	16.40	0.0	1	15.00	15.00	0.0	MC+WC
					2	14.90	16.40	15.0	
4	1	18.00	18.00	0.0	1	15.00	15.00	0.0	WC
					2	14.90	16.40	15.0	

WALL PROPERTIES

Type of structure = Fully Embedded Wall
Elevation of toe of wall = 12.00
Maximum finite element length = 0.40 m
Youngs modulus of wall E = 2.2600E+07 kN/m2
Moment of inertia of wall I = 1.3400E-03 m4/m run
E.I = 30284 kN.m2/m run
Yield Moment of wall = Not defined

STRUTS and ANCHORS

Strut/ anchor no.	Elev.	Strut spacing m	X-section area of strut sq.m	Youngs modulus kN/m2	Free length m	Inclin -ation (degs)	Pre- stress /strut kN	Tension allowed
1	18.50	5.00	0.020000	2.000E+08	5.00	0.00	0	No
2	19.20	1.00	0.400000	2.000E+07	5.00	0.00	0	No
3	15.20	1.00	0.400000	2.000E+07	5.00	0.00	0	No

SURCHARGE LOADS

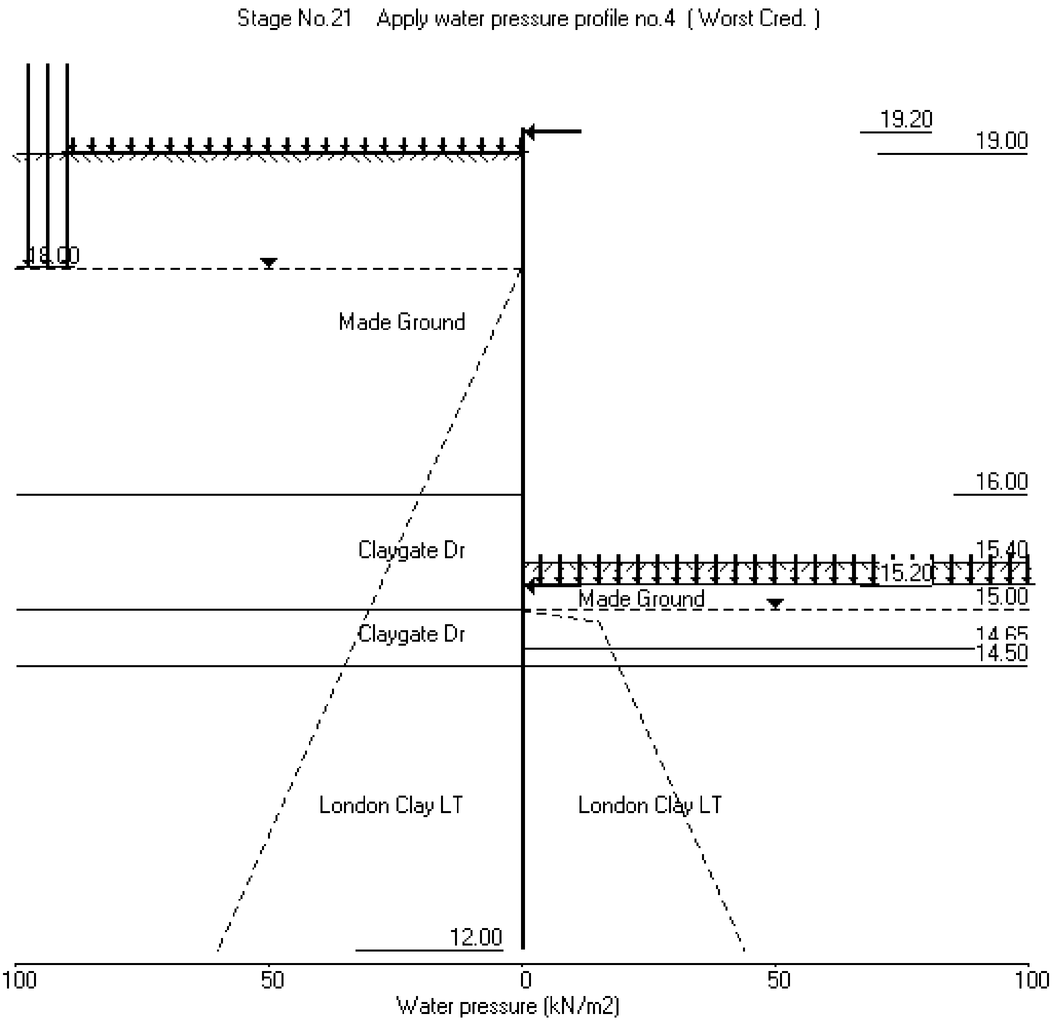
Surch -arge no.	Elev.	Distance from wall	Length parallel to wall	Width perpend. to wall	Surcharge kN/m2 Near edge	Surcharge kN/m2 Far edge	Equiv. soil type	Partial factor/ Category
1	18.00	4.00(A)	100.00	1.00	115.00	=	N/A	1.00 -
2	18.00	4.00(A)	100.00	1.00	17.00	=	N/A	1.00 -
3	19.00	0.00(A)	100.00	4.00	10.00	=	N/A	1.00 -
4	15.20	-0.00(P)	100.00	100.00	20.00	=	N/A	1.00 -

Note: A = Active side, P = Passive side
Limit State Categories P/U = Permanent Unfavourable
P/F = Permanent Favourable
Var = Variable (unfavourable)

```
CONSTRUCTION STAGES
Construction   Stage description
  stage no.    -------------------------------------------------------
      1        Change EI of wall to 100.00 kN.m2/m run
               100.00 kN.m2/m run
               No adjustments to wall displacements
      2        Apply surcharge no.1 at elevation 18.00
      3        Change EI of wall to 30284 kN.m2/m run
               30284 kN.m2/m run
               Reset wall displacements to zero at this stage
      4        Apply surcharge no.2 at elevation 18.00
      5        Apply surcharge no.3 at elevation 19.00
      6        Excavate to elevation 18.00 on PASSIVE side
      7        Install strut or anchor no.1 at elevation 18.50
      8        Apply water pressure profile no.2  ( Worst Cred. )
      9        Excavate to elevation 14.65 on PASSIVE side
     10        Change properties of soil type 3 to soil type 5
               Ko pressures will not be reset
     11        Fill to elevation 15.40 on PASSIVE side with soil type 1
     12        Install strut or anchor no.3 at elevation 15.20
     13        Install strut or anchor no.2 at elevation 19.20
     14        Remove strut or anchor no.1 at elevation 18.50
     15        Apply surcharge no.4 at elevation 15.20
     16        Apply water pressure profile no.3  ( Worst Cred. )
     17        Change properties of soil type 2 to soil type 6
               Ko pressures will not be reset
     18        Change properties of soil type 5 to soil type 6
               Ko pressures will not be reset
     19        Change properties of soil type 4 to soil type 7
               Ko pressures will not be reset
     20        Change EI of wall to 21640 kN.m2/m run
               Yield moment not defined
               Allow wall to relax with new modulus value
     21        Apply water pressure profile no.4  ( Worst Cred. )

FACTORS OF SAFETY and ANALYSIS OPTIONS
   Limit State options: ULS DA1 Combination 1
      Water pressures : Worst Credible
      Partial factor on   C'         = 1.000
      Partial factor on Phi'         = 1.000
      Partial factor on   Cu         = 1.000
      Partial factor on Soil Modulus = 1.000
      Partial factor on Permanent Unfavourable loads = 1.000
      Partial factor on Permanent Favourable loads   = 1.000
      Partial factor on Permanent Variable loads     = 1.100
      Design factor on calculated Bending Moments    = 1.350


   Parameters for undrained strata:
      Minimum equivalent fluid density             =   5.00 kN/m3
      Maximum depth of water filled tension crack  =   0.00 m

   Bending moment and displacement calculation:
      Method  -  Subgrade reaction model using Influence Coefficients
      Open Tension Crack analysis? - No
      Non-linear Modulus Parameter (L) = 0 m

   Boundary conditions:
      Length of wall (normal to plane of analysis) = 1000.00 m
```

```
Width of excavation on active  side of wall  = 20.00 m
Width of excavation on passive side of wall  = 20.00 m

Distance to rigid boundary on active side  = 20.00 m
Distance to rigid boundary on passive side = 20.00 m
```

Units: kN,m



Units: kN,m

Summary of results

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 1000.00m
Subgrade reaction model - Boussinesq Influence coefficients
Soil deformations are elastic until the active or passive limit is reached
Open Tension Crack analysis - No

Rigid boundaries: Active side 20.00 from wall
Passive side 20.00 from wall

Limit State: ULS DA1 Combination 1

Calculated Bending Moments and Strut Forces have been multiplied by a factor of 1.35 to obtain values for structural design.

Bending moment, shear force and displacement envelopes

Node no.	Y coord	Displacement max. m	Displacement min. m	Bending moment Calculated max. kN.m/m	Bending moment Calculated min. kN.m/m	Bending moment Factored max. kN.m/m	Bending moment Factored min. kN.m/m	Shear force Calculated max. kN/m	Shear force Calculated min. kN/m	Shear force Factored max. kN/m	Shear force Factored min. kN/m
1	19.20	0.005	-0.000	0	-0	0	-0	0	-31	0	-42
2	19.00	0.005	-0.000	0	-6	0	-8	0	-31	0	-42
3	18.75	0.005	-0.000	1	-13	1	-18	4	-27	6	-36
4	18.50	0.006	-0.000	2	-20	3	-27	7	-31	9	-42
5	18.25	0.006	0.000	1	-26	2	-35	4	-30	6	-40
6	18.00	0.007	0.000	3	-31	4	-42	6	-27	9	-37
7	17.60	0.008	0.000	6	-38	8	-52	7	-23	10	-31
8	17.20	0.008	0.000	8	-44	11	-60	5	-18	7	-24
9	16.80	0.008	0.000	10	-48	13	-64	3	-12	4	-16
10	16.40	0.008	0.000	11	-48	14	-65	12	-4	16	-6
11	16.00	0.008	0.000	11	-46	15	-62	26	-0	34	-0
12	15.70	0.007	0.000	11	-41	14	-55	40	-2	53	-3
13	15.40	0.007	0.000	10	-34	13	-46	55	-4	74	-5
14	15.20	0.007	0.000	9	-30	12	-40	66	-16	89	-21
15	15.00	0.007	0.000	8	-25	11	-34	36	-6	49	-8
16	14.65	0.006	0.000	7	-13	9	-17	49	-3	66	-4
17	14.50	0.006	0.000	6	-6	8	-9	46	-2	62	-3
18	14.25	0.005	0.000	11	-0	15	-0	28	-3	38	-4
19	14.00	0.005	0.000	16	-0	22	-0	16	-4	22	-5
20	13.60	0.004	0.000	17	-0	23	-0	4	-3	6	-5
21	13.20	0.004	0.000	14	-0	18	-0	0	-12	0	-16
22	12.80	0.003	0.000	8	-0	11	-0	0	-14	0	-19
23	12.40	0.003	0.000	3	-0	3	-0	0	-10	0	-13
24	12.00	0.002	0.000	0	-0	0	-0	0	-0	0	-0

Calculated Bending Moments and Strut Forces have been multiplied by a factor of 1.35 to obtain values for structural design.

Maximum and minimum bending moment and shear force at each stage

Stage no.	BM Calculated max. kN.m/m	elev.	BM Calculated min. kN.m/m	elev.	BM Factored max. kN.m/m	BM Factored min. kN.m/m	SF Calculated max. kN/m	elev.	SF Calculated min. kN/m	elev.	SF Factored max. kN/m	SF Factored min. kN/m
1	0	13.60	-0	14.25	0	-0	0	19.20	0	19.20	0	0
2	0	14.25	-0	15.00	0	-0	0	14.50	-0	15.20	0	-0
3	No calculation at this stage											
4	0	17.20	-0	14.65	0	-0	0	14.50	-0	15.20	0	-0
5	1	14.25	-0	19.00	1	-0	1	18.50	-1	13.20	1	-1
6	11	16.00	-0	19.20	15	-0	7	17.60	-4	15.20	10	-6
7	No calculation at this stage											
8	11	16.00	-0	19.20	14	-0	7	17.60	-4	15.20	9	-5
9	10	13.60	-39	16.00	14	-53	43	14.65	-31	18.50	58	-42
10	11	13.60	-39	16.00	14	-53	43	14.65	-31	18.50	58	-42
11	12	13.60	-40	16.00	16	-54	45	14.65	-31	18.50	61	-42
12	No calculation at this stage											
13	No calculation at this stage											
14	13	13.60	-42	16.80	18	-57	40	14.65	-29	19.20	54	-39
15	16	13.60	-46	16.40	22	-62	49	14.65	-30	19.20	66	-41
16	16	13.60	-45	16.40	22	-61	47	14.65	-30	19.20	64	-40
17	17	13.60	-48	16.40	23	-65	48	14.65	-31	19.20	65	-42

18	17	13.60	-48	16.40	23	-65	46	14.50	-31	19.20	62	-42
19	10	13.60	-44	16.80	14	-59	43	15.20	-30	19.20	59	-40
20	12	13.60	-39	16.80	16	-52	45	15.20	-27	19.20	61	-36
21	10	13.60	-43	16.80	14	-58	66	15.20	-29	19.20	89	-39

Maximum and minimum displacement at each stage

Stage no.	Displacement maximum m	elev.	minimum m	elev.	Stage description
1	0.000	14.00	-0.000	17.60	Change EI of wall to 100.00kN.m2/m run
2	0.000	12.00	-0.000	18.25	Apply surcharge no.1 at elev. 18.00
3	Wall displacements reset to zero				Change EI of wall to 30284kN.m2/m run
4	0.000	12.00	-0.000	19.20	Apply surcharge no.2 at elev. 18.00
5	0.001	19.20	0.000	19.20	Apply surcharge no.3 at elev. 19.00
6	0.005	19.20	0.000	19.20	Excav. to elev. 18.00 on PASSIVE side
7	No calculation at this stage				Install strut no.1 at elev. 18.50
8	0.005	19.20	0.000	19.20	Apply water pressure profile no.2
9	0.007	16.40	0.000	19.20	Excav. to elev. 14.65 on PASSIVE side
10	0.007	16.40	0.000	19.20	Change soil type 3 to soil type 5
11	0.007	16.40	0.000	19.20	Fill to elev. 15.40 on PASSIVE side
12	No calculation at this stage				Install strut no.3 at elev. 15.20
13	No calculation at this stage				Install strut no.2 at elev. 19.20
14	0.008	16.40	0.000	19.20	Remove strut no.1 at elev. 18.50
15	0.008	16.40	0.000	19.20	Apply surcharge no.4 at elev. 15.20
16	0.008	16.40	0.000	19.20	Apply water pressure profile no.3
17	0.008	16.40	0.000	19.20	Change soil type 2 to soil type 6
18	0.008	16.40	0.000	19.20	Change soil type 5 to soil type 6
19	0.008	16.40	0.000	19.20	Change soil type 4 to soil type 7
20	0.008	16.80	0.000	19.20	Change EI of wall to 21640kN.m2/m run
21	0.008	16.80	0.000	19.20	Apply water pressure profile no.4

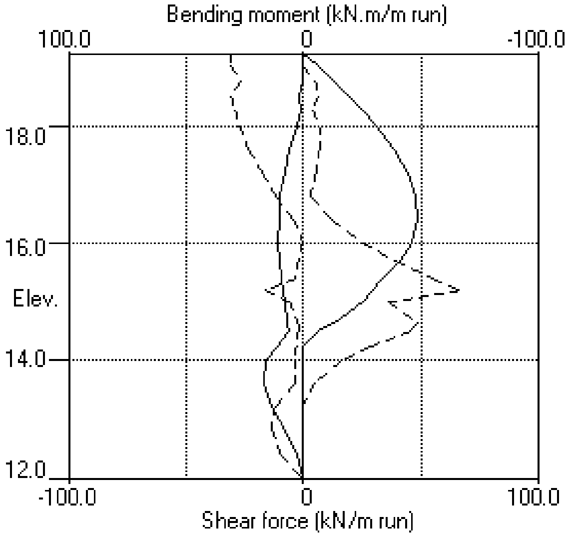
Calculated Bending Moments and Strut Forces have been multiplied by a factor of 1.35 to obtain values for structural design.

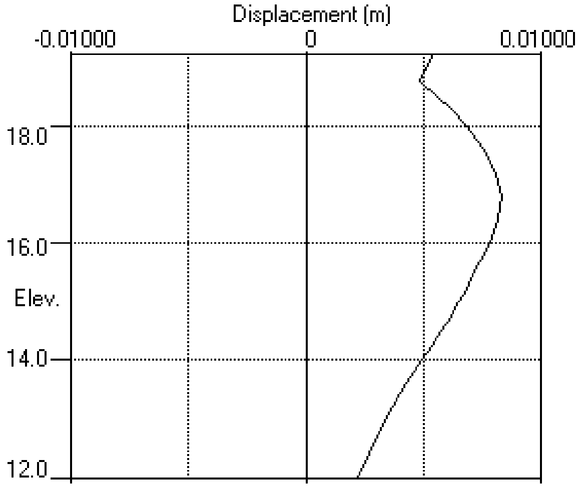
Strut forces at each stage (horizontal components)

Stage no.	Strut no. 1 at elev. 18.50 Calculated kN per m run	Calculated kN per strut	Factored kN per strut	Strut no. 2 at elev. 19.20 Calculated kN per m run	Calculated kN per strut	Factored kN per strut	Strut no. 3 at elev. 15.20 Calculated kN per m run	Calculated kN per strut	Factored kN per strut
8	0	1	1	---	---	---	---	---	---
9	37	187	252	---	---	---	---	---	---
10	37	187	253	---	---	---	---	---	---
11	38	189	255	---	---	---	---	---	---
14	---	---	---	29	29	39	12	12	17
15	---	---	---	30	30	41	slack	slack	slack
16	---	---	---	30	30	40	slack	slack	slack
17	---	---	---	31	31	42	12	12	16
18	---	---	---	31	31	42	15	15	21
19	---	---	---	30	30	40	35	35	47
20	---	---	---	27	27	36	43	43	57
21	---	---	---	29	29	39	82	82	111

* Indicates that the total force shown is the sum of the force in the strut plus a force applied at the same elevation which may represent temperature load or other forces which are part of the strut load. Force components are listed in the detailed results for individual stages.

Bending moment, shear force, displacement envelopes





APPENDIX B – WALLAP INPUT / OUTPUT – COM 2

```
SOUTHERN GEOTECHNICAL DESIGN                                  | Sheet No.
Program: WALLAP  Version 6.05  Revision A45.B58.R49           | Job No.   C0745
                             Licensed from GEOSOLVE           | Made by :    MP
Data filename/Run ID: Com 2                                   |
66 Fitzjohns Avenue, London NW3 5LT                           | Date:23-05-2016
Com 2                                                         | Checked :
------------------------------------------------------------------------------
                                                       Units: kN,m
```

INPUT DATA

SOIL PROFILE

Stratum no.	Elevation of top of stratum	Soil types – Active side	Soil types – Passive side
1	19.00	1 Made Ground	1 Made Ground
2	16.00	2 Claygate Undr	2 Claygate Undr
3	15.00	2 Claygate Undr	3 Claygate To soft
4	14.50	4 London Clay Undr	4 London Clay Undr

SOIL PROPERTIES (Unfactored SLS soil strengths)

-- Soil type -- No.	Description (Datum elev.)	Bulk density kN/m3	Young's Modulus Eh,kN/m2 (dEh/dy)	At rest coeff. Ko (dKo/dy)	Consol state. NC/OC (Nu)	Active limit Ka (Kac)	Passive limit Kp (Kpc)	Cohesion kN/m2 (dc/dy)
1	Made Ground	18.00	10000	0.500	OC (0.200)	0.333 (0.000)	4.369 (0.000)	
2	Claygate Undr	20.00	32000	1.000	OC (0.490)	1.000 (2.000)	1.000 (2.000)	32.00u
3	Claygate To soft	20.00	32000	1.000	OC (0.490)	1.000 (2.000)	1.000 (2.000)	32.00u
4	London Cl.. (14.50)	20.00	44000 (1520)	1.000	OC (0.490)	1.000 (2.000)	1.000 (2.390)	44.00u (1.520)
5	Claygate .. (15.00)	20.00	1 (64000)	1.000	OC (0.490)	1.000 (2.000)	1.000 (2.000)	1.000u (64.00)
6	Claygate Dr	20.00	22400	1.000	OC (0.150)	0.455 (1.349)	2.198 (2.965)	0.0d
7	London Cl.. (14.50)	20.00	30800 (1070)	1.000	OC (0.150)	0.422 (1.299)	3.077 (4.665)	0.0d

Additional soil parameters associated with Ka and Kp

------- Soil type ------- No.	Description	Ka: Soil friction angle	Ka: Wall adhesion coeff.	Ka: Back-fill angle	Kp: Soil friction angle	Kp: Wall adhesion coeff.	Kp: Back-fill angle
1	Made Ground	30.00	0.000	0.00	30.00	0.500	0.00
2	Claygate Undr	0.00	0.000	0.00	0.00	0.000	0.00
3	Claygate To soft	0.00	0.000	0.00	0.00	0.000	0.00
4	London Clay Undr	0.00	0.000	0.00	0.00	0.500	0.00
5	Claygate Soft	0.00	0.000	0.00	0.00	0.000	0.00
6	Claygate Dr	22.00	0.000	0.00	22.00	0.000	0.00
7	London Clay LT	24.00	0.000	0.00	24.00	0.500	0.00

GROUND WATER CONDITIONS

Density of water = 10.00 kN/m3

	Active side	Passive side
Initial water table elevation	16.40	16.40

Automatic water pressure balancing at toe of wall : No

Water press. profile no.	Active side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	Passive side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	
1	1	16.40	16.40	0.0	1	15.00	15.00	0.0	MC
					2	13.00	16.40	34.0	
2	1	16.40	16.40	0.0	1	14.65	14.65	0.0	WC
					2	12.60	16.40	38.0	
3	1	16.40	16.40	0.0	1	15.00	15.00	0.0	MC+WC
					2	14.90	16.40	15.0	
4	1	18.00	18.00	0.0	1	15.00	15.00	0.0	WC
					2	14.90	16.40	15.0	

WALL PROPERTIES

Type of structure = Fully Embedded Wall
Elevation of toe of wall = 12.00
Maximum finite element length = 0.40 m
Youngs modulus of wall E = 2.2600E+07 kN/m2
Moment of inertia of wall I = 1.3400E-03 m4/m run
E.I = 30284 kN.m2/m run
Yield Moment of wall = Not defined

STRUTS and ANCHORS

Strut/ anchor no.	Elev.	Strut spacing m	X-section area of strut sq.m	Youngs modulus kN/m2	Free length m	Inclin -ation (degs)	Pre- stress /strut kN	Tension allowed
1	18.50	5.00	0.020000	2.000E+08	5.00	0.00	0	No
2	19.20	1.00	0.400000	2.000E+07	5.00	0.00	0	No
3	15.20	1.00	0.400000	2.000E+07	5.00	0.00	0	No

SURCHARGE LOADS

Surch -arge no.	Elev.	Distance from wall	Length parallel to wall	Width perpend. to wall	Surcharge kN/m2 Near edge	Surcharge kN/m2 Far edge	Equiv. soil type	Partial factor/ Category
1	18.00	4.00(A)	100.00	1.00	115.00	=	N/A	1.00 -
2	18.00	4.00(A)	100.00	1.00	17.00	=	N/A	1.00 -
3	19.00	0.00(A)	100.00	4.00	10.00	=	N/A	1.00 -
4	15.20	-0.00(P)	100.00	100.00	20.00	=	N/A	1.00 -

Note: A = Active side, P = Passive side
Limit State Categories P/U = Permanent Unfavourable
P/F = Permanent Favourable
Var = Variable (unfavourable)

CONSTRUCTION STAGES

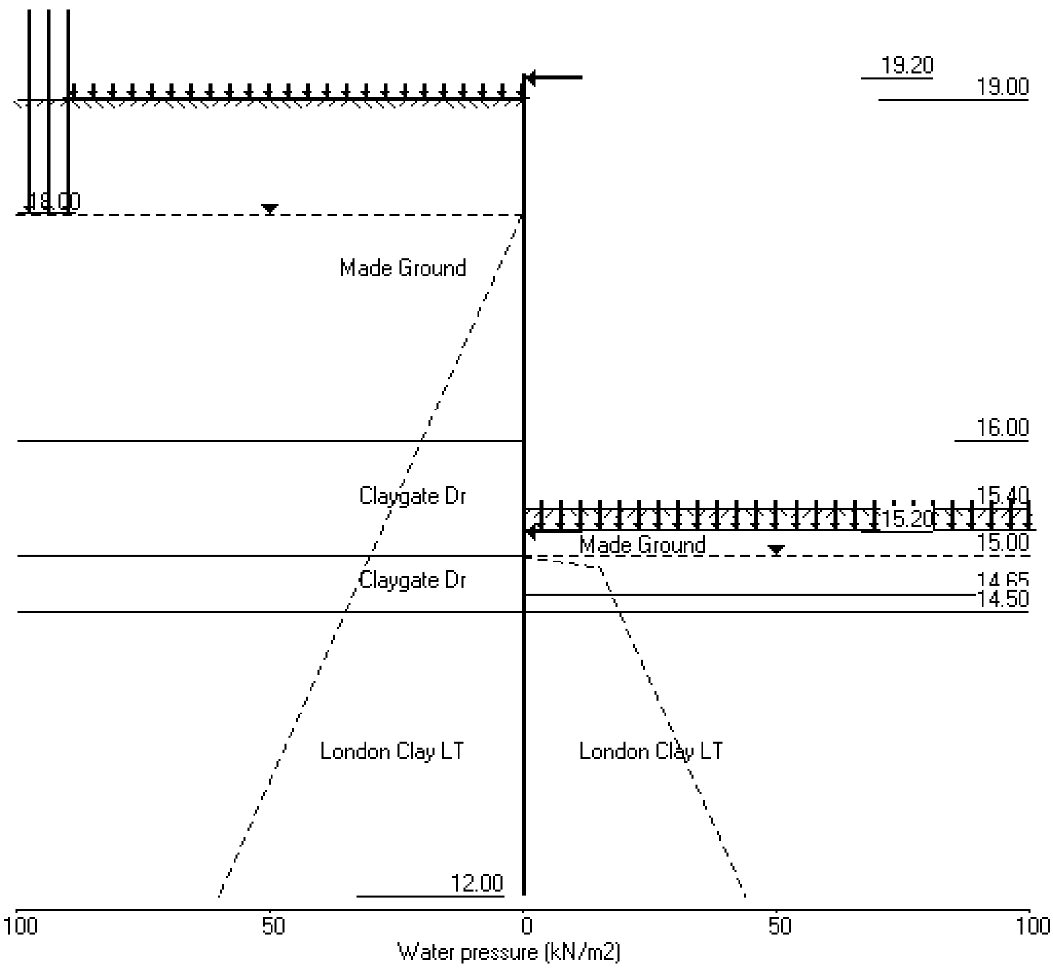
```
Construction   Stage description
  stage no.    -------------------------------------------------------
      1        Change EI of wall to 100.00 kN.m2/m run
               100.00 kN.m2/m run
               No adjustments to wall displacements
      2        Apply surcharge no.1 at elevation 18.00
      3        Change EI of wall to 30284 kN.m2/m run
               30284 kN.m2/m run
               Reset wall displacements to zero at this stage
      4        Apply surcharge no.2 at elevation 18.00
      5        Apply surcharge no.3 at elevation 19.00
      6        Excavate to elevation 18.00 on PASSIVE side
      7        Install strut or anchor no.1 at elevation 18.50
      8        Apply water pressure profile no.2  ( Worst Cred. )
      9        Excavate to elevation 14.65 on PASSIVE side
     10        Change properties of soil type 3 to soil type 5
               Ko pressures will not be reset
     11        Fill to elevation 15.40 on PASSIVE side with soil type 1
     12        Install strut or anchor no.3 at elevation 15.20
     13        Install strut or anchor no.2 at elevation 19.20
     14        Remove strut or anchor no.1 at elevation 18.50
     15        Apply surcharge no.4 at elevation 15.20
     16        Apply water pressure profile no.3  ( Worst Cred. )
     17        Change properties of soil type 2 to soil type 6
               Ko pressures will not be reset
     18        Change properties of soil type 5 to soil type 6
               Ko pressures will not be reset
     19        Change properties of soil type 4 to soil type 7
               Ko pressures will not be reset
     20        Change EI of wall to 21640 kN.m2/m run
               Yield moment not defined
               Allow wall to relax with new modulus value
     21        Apply water pressure profile no.4  ( Worst Cred. )
```

FACTORS OF SAFETY and ANALYSIS OPTIONS

```
   Limit State options: ULS DA1 Combination 2
      Water pressures : Worst Credible
      Partial factor on   C'         = 1.250
      Partial factor on Phi'         = 1.250
      Partial factor on   Cu         = 1.400
      Partial factor on Soil Modulus = 1.000
      Partial factor on Permanent Unfavourable loads = 1.000
      Partial factor on Permanent Favourable loads   = 1.000
      Partial factor on Permanent Variable loads     = 1.300

   Stability analysis:
      Method of analysis  -  Strength Factor method
      Overall factor on soil strength for calculating wall depth = 1.20

   Parameters for undrained strata:
      Minimum equivalent fluid density            =   5.00 kN/m3
      Maximum depth of water filled tension crack  =   0.00 m

   Bending moment and displacement calculation:
      Method  -  Subgrade reaction model using Influence Coefficients
      Open Tension Crack analysis? - No
      Non-linear Modulus Parameter (L) = 0 m

   Boundary conditions:
```

```
Length of wall (normal to plane of analysis) = 1000.00 m

Width of excavation on active  side of wall  = 20.00 m
Width of excavation on passive side of wall  = 20.00 m

Distance to rigid boundary on active side  = 20.00 m
Distance to rigid boundary on passive side = 20.00 m
```

Stage No.21 Apply water pressure profile no.4 (Worst Cred.)



Summary of results

LIMIT STATE PARAMETERS

```
Limit State: ULS DA1 Combination 2
Water pressures : Worst Credible
Partial factor on   C'          = 1.250
Partial factor on Phi'          = 1.250
Partial factor on   Cu          = 1.400
Partial factor on Soil Modulus = 1.000
Partial factor on Permanent Unfavourable loads = 1.000
Partial factor on Permanent Favourable loads   = 1.000
```

Partial factor on Permanent Variable loads = 1.300

STABILITY ANALYSIS of Fully Embedded Wall according to Strength Factor method

Factor of safety on soil strength

Stage No.	--- G.L. --- Act.	Pass.	Strut Elev.	Overall FoS for toe elev. = 12.00 Factor of Safety	Moment equilib. at elev.	Toe elev. for FoS = 1.200 Toe elev.	Wall Penetr -ation
1	19.00	19.00	Cant.	Conditions not suitable for FoS calc.			
2	19.00	19.00	Cant.	Conditions not suitable for FoS calc.			
3	19.00	19.00		No analysis at this stage			
4	19.00	19.00	Cant.	Conditions not suitable for FoS calc.			
5	19.00	19.00	Cant.	6.595	12.30	18.70	0.30
6	19.00	18.00	Cant.	2.242	12.56	15.82	2.18
7	19.00	18.00		No analysis at this stage			
8	19.00	18.00	18.50	3.691	n/a	17.43	0.57
9	19.00	14.65	18.50	1.219	n/a	12.18	2.47
10	19.00	14.65	18.50	1.217	n/a	12.16	2.49
11	19.00	15.40	18.50	1.391	n/a	13.15	2.25
12	19.00	15.40		No analysis at this stage			

All remaining stages have more than one strut - FoS calculation n/a

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 1000.00m
Subgrade reaction model - Boussinesq Influence coefficients
Soil deformations are elastic until the active or passive limit is reached
Open Tension Crack analysis - No

Rigid boundaries: Active side 20.00 from wall
Passive side 20.00 from wall

Limit State: ULS DA1 Combination 2

Bending moment, shear force and displacement envelopes

Node no.	Y coord	Displacement maximum m	Displacement minimum m	Bending moment maximum kN.m/m	Bending moment minimum kN.m/m	Shear force maximum kN/m	Shear force minimum kN/m
1	19.20	0.007	-0.000	0.0	-0.0	0.0	-40.3
2	19.00	0.007	-0.000	0.0	-8.1	0.0	-40.3
3	18.75	0.006	-0.000	1.0	-17.2	5.8	-34.9
4	18.50	0.007	-0.000	3.0	-25.4	8.8	-41.6
5	18.25	0.008	0.000	1.7	-33.2	5.1	-39.4
6	18.00	0.009	0.000	3.3	-40.3	7.8	-36.8
7	17.60	0.010	0.000	7.1	-49.9	8.9	-31.6
8	17.20	0.010	0.000	10.2	-57.6	6.9	-25.2
9	16.80	0.011	0.000	12.6	-62.4	5.3	-17.5
10	16.40	0.011	0.000	14.5	-64.0	13.9	-8.6
11	16.00	0.010	0.000	16.0	-61.8	29.1	-0.0
12	15.70	0.010	0.000	16.1	-56.8	44.7	-1.4
13	15.40	0.009	0.000	15.1	-51.3	61.8	-4.4
14	15.20	0.009	0.000	14.1	-46.9	73.8	-26.1
15	15.00	0.009	0.000	12.9	-41.2	41.6	-15.4
16	14.65	0.008	0.000	10.8	-27.2	53.1	-5.5
17	14.50	0.008	0.000	10.0	-19.8	51.6	-4.9
18	14.25	0.007	0.000	8.7	-10.4	39.6	-5.7

19	14.00	0.006	0.000	8.9	-5.6	28.6	-5.9
20	13.60	0.005	0.000	15.9	-0.0	11.9	-5.5
21	13.20	0.005	0.000	15.0	-0.0	3.6	-8.1
22	12.80	0.004	0.000	11.0	-0.0	0.0	-15.9
23	12.40	0.003	0.000	3.9	-0.0	0.0	-13.8
24	12.00	0.002	-0.000	0.0	-0.0	0.0	-0.0

Maximum and minimum bending moment and shear force at each stage

Stage	--------- Bending moment --------				---------- Shear force ----------			
no.	maximum kN.m/m	elev.	minimum kN.m/m	elev.	maximum kN/m	elev.	minimum kN/m	elev.
1	0.0	13.60	-0.0	14.25	0.0	19.20	0.0	19.20
2	0.0	14.25	-0.0	15.00	0.2	14.50	-0.1	15.20
3	No calculation at this stage							
4	0.0	17.20	-0.1	14.65	0.2	14.50	-0.1	15.20
5	2.1	16.00	-0.0	19.00	1.1	18.00	-0.8	13.60
6	16.1	15.70	0.0	19.20	8.9	17.60	-6.0	15.00
7	No calculation at this stage							
8	15.8	15.70	0.0	19.20	8.7	17.60	-5.9	15.00
9	10.6	13.20	-55.9	16.00	49.4	14.50	-41.0	18.50
10	10.6	13.20	-56.4	16.00	50.1	14.50	-41.2	18.50
11	11.5	13.20	-57.0	16.00	50.9	14.50	-41.6	18.50
12	No calculation at this stage							
13	No calculation at this stage							
14	12.3	13.20	-58.1	16.40	44.9	14.50	-38.3	19.20
15	15.3	13.60	-62.2	16.40	53.1	14.65	-39.7	19.20
16	15.6	13.60	-62.4	16.40	52.8	14.65	-39.8	19.20
17	15.9	13.60	-64.0	16.40	51.8	14.65	-40.3	19.20
18	15.7	13.60	-63.8	16.40	51.3	14.50	-40.3	19.20
19	5.5	12.80	-54.6	16.80	50.7	15.20	-37.5	19.20
20	6.0	12.80	-47.6	16.80	52.5	15.20	-33.3	19.20
21	4.3	12.80	-51.6	16.80	73.8	15.20	-35.7	19.20

Maximum and minimum displacement at each stage

Stage	-------- Displacement ---------				Stage description
no.	maximum m	elev.	minimum m	elev.	-----------------
1	0.000	14.00	-0.000	17.60	Change EI of wall to 100.00kN.m2/m run
2	0.000	12.00	-0.000	18.25	Apply surcharge no.1 at elev. 18.00
3	Wall displacements reset to zero				Change EI of wall to 30284kN.m2/m run
4	0.000	12.00	-0.000	19.20	Apply surcharge no.2 at elev. 18.00
5	0.001	19.20	0.000	19.20	Apply surcharge no.3 at elev. 19.00
6	0.007	19.20	0.000	19.20	Excav. to elev. 18.00 on PASSIVE side
7	No calculation at this stage				Install strut no.1 at elev. 18.50
8	0.007	19.20	0.000	19.20	Apply water pressure profile no.2
9	0.010	16.00	0.000	19.20	Excav. to elev. 14.65 on PASSIVE side
10	0.010	16.00	0.000	19.20	Change soil type 3 to soil type 5
11	0.010	16.40	0.000	19.20	Fill to elev. 15.40 on PASSIVE side
12	No calculation at this stage				Install strut no.3 at elev. 15.20
13	No calculation at this stage				Install strut no.2 at elev. 19.20
14	0.010	16.40	0.000	19.20	Remove strut no.1 at elev. 18.50
15	0.010	16.40	0.000	19.20	Apply surcharge no.4 at elev. 15.20
16	0.010	16.40	-0.000	12.00	Apply water pressure profile no.3
17	0.010	16.40	-0.000	12.00	Change soil type 2 to soil type 6
18	0.010	16.40	-0.000	12.00	Change soil type 5 to soil type 6
19	0.010	16.40	0.000	19.20	Change soil type 4 to soil type 7
20	0.010	16.40	0.000	19.20	Change EI of wall to 21640kN.m2/m run
21	0.011	16.80	0.000	19.20	Apply water pressure profile no.4

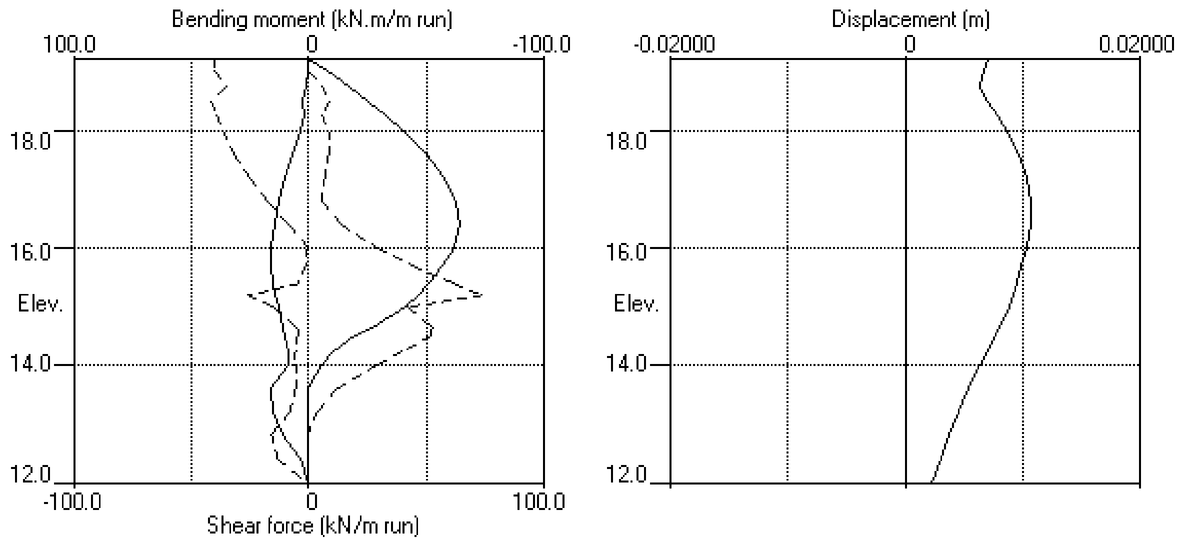
Strut forces at each stage (horizontal components)

Stage no.	--- Strut no. 1 --- at elev. 18.50 kN/m run	kN/strut	--- Strut no. 2 --- at elev. 19.20 kN/m run	kN/strut	--- Strut no. 3 --- at elev. 15.20 kN/m run	kN/strut
8	0.21	1.07	---	---	---	---
9	49.75	248.75	---	---	---	---
10	50.02	250.09	---	---	---	---
11	50.26	251.29	---	---	---	---
14	---	---	38.29	38.29	16.66	16.66
15	---	---	39.72	39.72	1.99	1.99
16	---	---	39.78	39.78	slack	slack
17	---	---	40.35	40.35	14.65	14.65
18	---	---	40.27	40.27	16.78	16.78
19	---	---	37.53	37.53	50.97	50.97
20	---	---	33.31	33.31	59.62	59.62
21	---	---	35.68	35.68	99.87	99.87

* Indicates that the total force shown is the sum of the force in the strut plus a force applied at the same elevation which may represent temperature load or other forces which are part of the strut load. Force components are listed in the detailed results for individual stages.

Units: kN,m

Bending moment, shear force, displacement envelopes



APPENDIX B – WALLAP INPUT / OUTPUT – SLS

```
SOUTHERN GEOTECHNICAL DESIGN                                 | Sheet No.
Program: WALLAP  Version 6.05  Revision A45.B58.R49          | Job No.   C0745
                           Licensed from GEOSOLVE            | Made by :    MP
Data filename/Run ID: SLS                                    |
66 Fitzjohns Avenue, London NW3 5LT                          | Date:23-05-2016
SLS                                                          | Checked :
------------------------------------------------------------------------------
                                                       Units: kN,m
```

INPUT DATA

SOIL PROFILE

Stratum no.	Elevation of top of stratum	Soil types – Active side	Soil types – Passive side
1	19.00	1 Made Ground	1 Made Ground
2	16.00	2 Claygate Undr	2 Claygate Undr
3	15.00	2 Claygate Undr	3 Claygate To soft
4	14.50	4 London Clay Undr	4 London Clay Undr

SOIL PROPERTIES

No.	-- Soil type -- Description (Datum elev.)	Bulk density kN/m3	Young's Modulus Eh,kN/m2 (dEh/dy)	At rest coeff. Ko (dKo/dy)	Consol state. NC/OC (Nu)	Active limit Ka (Kac)	Passive limit Kp (Kpc)	Cohesion kN/m2 (dc/dy)
1	Made Ground	18.00	10000	0.500	OC	0.333	4.369	
					(0.200)	(0.000)	(0.000)	
2	Claygate Undr	20.00	32000	1.000	OC	1.000	1.000	32.00u
					(0.490)	(2.000)	(2.000)	
3	Claygate To soft	20.00	32000	1.000	OC	1.000	1.000	32.00u
					(0.490)	(2.000)	(2.000)	
4	London Cl..	20.00	44000	1.000	OC	1.000	1.000	44.00u
	(14.50)		(1520)		(0.490)	(2.000)	(2.390)	(1.520)
5	Claygate ..	20.00	1	1.000	OC	1.000	1.000	1.000u
	(15.00)		(64000)		(0.490)	(2.000)	(2.000)	(64.00)
6	Claygate Dr	20.00	22400	1.000	OC	0.455	2.198	0.0d
					(0.150)	(1.349)	(2.965)	
7	London Cl..	20.00	30800	1.000	OC	0.422	3.077	0.0d
	(14.50)		(1070)		(0.150)	(1.299)	(4.665)	

Additional soil parameters associated with Ka and Kp

No.	------- Soil type ------- Description	Ka: Soil friction angle	Ka: Wall adhesion coeff.	Ka: Back-fill angle	Kp: Soil friction angle	Kp: Wall adhesion coeff.	Kp: Back-fill angle
1	Made Ground	30.00	0.000	0.00	30.00	0.500	0.00
2	Claygate Undr	0.00	0.000	0.00	0.00	0.000	0.00
3	Claygate To soft	0.00	0.000	0.00	0.00	0.000	0.00
4	London Clay Undr	0.00	0.000	0.00	0.00	0.500	0.00
5	Claygate Soft	0.00	0.000	0.00	0.00	0.000	0.00
6	Claygate Dr	22.00	0.000	0.00	22.00	0.000	0.00
7	London Clay LT	24.00	0.000	0.00	24.00	0.500	0.00

GROUND WATER CONDITIONS

Density of water = 10.00 kN/m3

	Active side	Passive side
Initial water table elevation	16.40	16.40

Automatic water pressure balancing at toe of wall : No

Water press. profile no.	Active side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	Passive side Point no.	Elev. m	Piezo elev. m	Water press. kN/m2	
1	1	16.40	16.40	0.0	1	15.00	15.00	0.0	MC
					2	13.00	16.40	34.0	
2	1	16.40	16.40	0.0	1	14.65	14.65	0.0	WC
					2	12.60	16.40	38.0	
3	1	16.40	16.40	0.0	1	15.00	15.00	0.0	MC+WC
					2	14.90	16.40	15.0	
4	1	18.00	18.00	0.0	1	15.00	15.00	0.0	WC
					2	14.90	16.40	15.0	

WALL PROPERTIES

Type of structure = Fully Embedded Wall
Elevation of toe of wall = 12.00
Maximum finite element length = 0.40 m
Youngs modulus of wall E = 2.2600E+07 kN/m2
Moment of inertia of wall I = 1.3400E-03 m4/m run
E.I = 30284 kN.m2/m run
Yield Moment of wall = Not defined

STRUTS and ANCHORS

Strut/ anchor no.	Elev.	Strut spacing m	X-section area of strut sq.m	Youngs modulus kN/m2	Free length m	Inclin -ation (degs)	Pre-stress /strut kN	Tension allowed
1	18.50	5.00	0.020000	2.000E+08	5.00	0.00	0	No
2	19.20	1.00	0.400000	2.000E+07	5.00	0.00	0	No
3	15.20	1.00	0.400000	2.000E+07	5.00	0.00	0	No

SURCHARGE LOADS

Surch -arge no.	Elev.	Distance from wall	Length parallel to wall	Width perpend. to wall	Surcharge kN/m2 Near edge	Surcharge kN/m2 Far edge	Equiv. soil type	Partial factor/ Category
1	18.00	4.00(A)	100.00	1.00	115.00	=	N/A	1.00 -
2	18.00	4.00(A)	100.00	1.00	17.00	=	N/A	1.00 -
3	19.00	0.00(A)	100.00	4.00	10.00	=	N/A	1.00 -
4	15.20	-0.00(P)	100.00	100.00	20.00	=	N/A	1.00 -

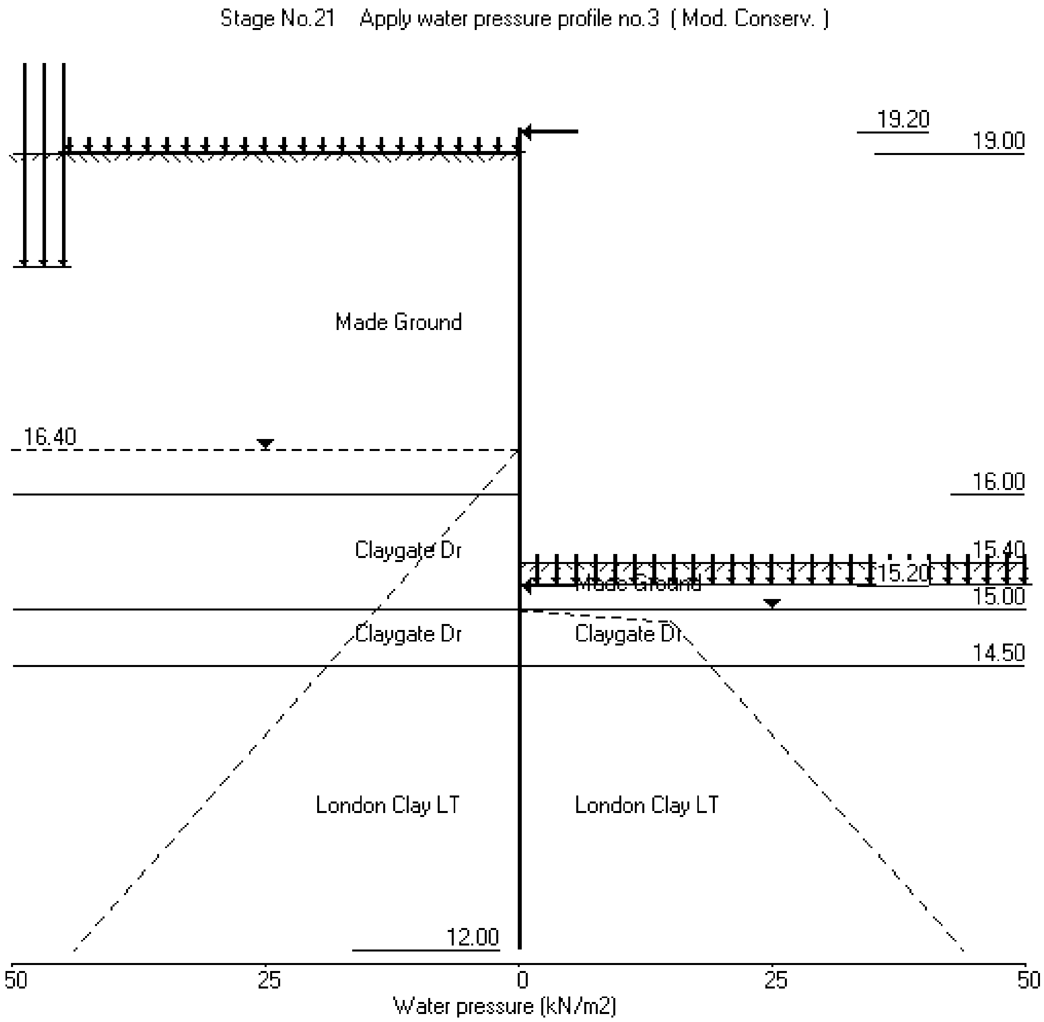
Note: A = Active side, P = Passive side
Limit State Categories P/U = Permanent Unfavourable
P/F = Permanent Favourable
Var = Variable (unfavourable)

CONSTRUCTION STAGES

```
Construction   Stage description
  stage no.    -------------------------------------------------------
     1         Change EI of wall to 100.00 kN.m2/m run
               100.00 kN.m2/m run
               No adjustments to wall displacements
     2         Apply surcharge no.1 at elevation 18.00
     3         Change EI of wall to 30284 kN.m2/m run
               30284 kN.m2/m run
               Reset wall displacements to zero at this stage
     4         Apply surcharge no.2 at elevation 18.00
     5         Apply surcharge no.3 at elevation 19.00
     6         Excavate to elevation 18.00 on PASSIVE side
     7         Install strut or anchor no.1 at elevation 18.50
     8         Apply water pressure profile no.1  ( Mod. Conserv. )
     9         Excavate to elevation 15.00 on PASSIVE side
    10         Change properties of soil type 3 to soil type 5
               Ko pressures will not be reset
    11         Fill to elevation 15.40 on PASSIVE side with soil type 1
    12         Install strut or anchor no.3 at elevation 15.20
    13         Install strut or anchor no.2 at elevation 19.20
    14         Remove strut or anchor no.1 at elevation 18.50
    15         Apply surcharge no.4 at elevation 15.20
    16         Apply water pressure profile no.3  ( Mod. Conserv. )
    17         Change properties of soil type 2 to soil type 6
               Ko pressures will not be reset
    18         Change properties of soil type 5 to soil type 6
               Ko pressures will not be reset
    19         Change properties of soil type 4 to soil type 7
               Ko pressures will not be reset
    20         Change EI of wall to 21640 kN.m2/m run
               Yield moment not defined
               Allow wall to relax with new modulus value
    21         Apply water pressure profile no.3  ( Mod. Conserv. )
```

FACTORS OF SAFETY and ANALYSIS OPTIONS

```
   Limit State options: Serviceability Limit State
      All loads and soil strengths are unfactored

   Stability analysis:
      Method of analysis  -  Strength Factor method
      Factor on soil strength for calculating wall depth = 1.00

   Parameters for undrained strata:
      Minimum equivalent fluid density             =   5.00 kN/m3
      Maximum depth of water filled tension crack  =   0.00 m

   Bending moment and displacement calculation:
      Method  -  Subgrade reaction model using Influence Coefficients
      Open Tension Crack analysis? - No
      Non-linear Modulus Parameter (L) = 0 m

   Boundary conditions:
      Length of wall (normal to plane of analysis) = 1000.00 m

      Width of excavation on active  side of wall  = 20.00 m
      Width of excavation on passive side of wall  = 20.00 m

      Distance to rigid boundary on active side  = 20.00 m
      Distance to rigid boundary on passive side = 20.00 m
```



Summary of results

LIMIT STATE PARAMETERS

Limit State: Serviceability Limit State

All loads and soil strengths are unfactored

STABILITY ANALYSIS of Fully Embedded Wall according to Strength Factor method

Factor of safety on soil strength

Stage No.	G.L. Act.	G.L. Pass.	Strut Elev.	FoS for toe elev. = 12.00: Factor of Safety	FoS for toe elev. = 12.00: Moment equilib. at elev.	Toe elev. for FoS = 1.000: Toe elev.	Toe elev. for FoS = 1.000: Wall Penetr -ation
1	19.00	19.00	Cant.	Conditions not suitable for FoS calc.			
2	19.00	19.00	Cant.	Conditions not suitable for FoS calc.			
3	19.00	19.00		No analysis at this stage			

4	19.00	19.00	Cant.	Conditions not suitable for FoS calc.			
5	19.00	19.00	Cant.	Conditions not suitable for FoS calc.			
6	19.00	18.00	Cant.	2.965	12.60	16.87	1.13
7	19.00	18.00		No analysis at this stage			
8	19.00	18.00	18.50	5.121	n/a	17.89	0.11
9	19.00	15.00	18.50	1.849	n/a	14.42	0.58
10	19.00	15.00	18.50	1.816	n/a	14.28	0.72
11	19.00	15.40	18.50	1.951	n/a	14.38	1.02
12	19.00	15.40		No analysis at this stage			

All remaining stages have more than one strut - FoS calculation n/a

BENDING MOMENT and DISPLACEMENT ANALYSIS of Fully Embedded Wall

Analysis options

Length of wall perpendicular to section = 1000.00m
Subgrade reaction model - Boussinesq Influence coefficients
Soil deformations are elastic until the active or passive limit is reached
Open Tension Crack analysis - No

Rigid boundaries: Active side 20.00 from wall
Passive side 20.00 from wall

Limit State: Serviceability Limit State

Calculated Bending Moments and Strut Forces have been multiplied by a factor of 1.35 to obtain values for structural design.

Bending moment, shear force and displacement envelopes

Node no.	Y coord	Displacement max. m	Displacement min. m	Bending moment Calculated max. kN.m/m	Bending moment Calculated min. kN.m/m	Bending moment Factored max. kN.m/m	Bending moment Factored min. kN.m/m	Shear force Calculated max. kN/m	Shear force Calculated min. kN/m	Shear force Factored max. kN/m	Shear force Factored min. kN/m
1	19.20	0.005	-0.000	0	-0	0	-0	0	-30	0	-41
2	19.00	0.005	-0.000	0	-6	0	-8	0	-30	0	-41
3	18.75	0.005	-0.000	1	-13	1	-17	4	-26	5	-35
4	18.50	0.005	-0.000	2	-19	3	-26	6	-30	9	-41
5	18.25	0.006	0.000	1	-25	2	-34	4	-28	6	-38
6	18.00	0.007	0.000	3	-30	4	-41	6	-26	9	-35
7	17.60	0.007	0.000	6	-37	8	-50	7	-22	10	-30
8	17.20	0.008	0.000	8	-43	11	-58	5	-17	7	-23
9	16.80	0.008	0.000	10	-46	13	-62	3	-11	4	-14
10	16.40	0.008	0.000	11	-46	14	-62	6	-3	8	-5
11	16.00	0.007	0.000	11	-44	15	-59	15	-0	20	-0
12	15.70	0.007	0.000	11	-38	14	-52	25	-2	34	-3
13	15.40	0.007	0.000	10	-31	13	-41	37	-4	50	-5
14	15.20	0.006	0.000	9	-27	12	-36	45	-4	61	-6
15	15.00	0.006	0.000	8	-21	11	-29	41	-4	56	-6
16	14.75	0.006	0.000	7	-12	10	-16	42	-4	57	-5
17	14.50	0.005	0.000	6	-3	8	-4	39	-2	53	-3
18	14.25	0.005	0.000	13	-0	18	-0	23	-3	32	-4
19	14.00	0.005	0.000	17	-0	23	-0	13	-4	18	-5
20	13.60	0.004	0.000	17	-0	23	-0	2	-4	3	-6
21	13.20	0.004	0.000	14	-0	18	-0	0	-12	0	-16
22	12.80	0.003	0.000	8	-0	11	-0	0	-13	0	-18
23	12.40	0.003	0.000	3	-0	4	-0	0	-10	0	-14
24	12.00	0.002	0.000	0	-0	0	-0	0	-0	0	-0

Calculated Bending Moments and Strut Forces have been multiplied by a factor of 1.35 to obtain values for structural design.

Maximum and minimum bending moment and shear force at each stage

Stage no.	Bending moment Calculated max. kN.m/m	elev.	min. kN.m/m	elev.	Factored max. kN.m/m	Factored min.	Shear force Calculated max. kN/m	elev.	min. kN/m	elev.	Factored max. kN/m	Factored min. kN/m
1	0	13.60	-0	14.00	0	-0	0	19.20	0	19.20	0	0
2	0	14.25	-0	14.75	0	-0	0	14.50	-0	15.20	0	-0
3	No calculation at this stage											
4	0	17.20	-0	14.75	0	-0	0	14.50	-0	15.20	0	-0
5	1	14.25	-0	19.20	1	-0	1	18.50	-1	13.20	1	-1
6	11	16.00	-0	19.20	15	-0	7	17.60	-4	15.20	10	-6
7	No calculation at this stage											
8	11	16.00	-0	19.20	14	-0	7	17.60	-4	15.20	9	-5
9	10	13.60	-35	16.40	13	-47	35	15.00	-29	18.50	47	-39
10	11	13.60	-38	16.40	15	-51	37	14.75	-30	18.50	50	-41
11	12	13.60	-38	16.40	16	-51	37	14.75	-30	18.50	50	-41
12	No calculation at this stage											
13	No calculation at this stage											
14	13	13.60	-40	16.80	17	-54	32	14.75	-28	19.20	44	-37
15	16	13.60	-43	16.40	21	-57	40	14.75	-29	19.20	54	-39
16	16	13.60	-43	16.80	21	-57	40	14.75	-29	19.20	54	-39
17	17	13.60	-46	16.40	23	-62	42	14.75	-30	19.20	57	-41
18	17	13.60	-46	16.40	22	-61	42	15.20	-30	19.20	56	-40
19	13	13.60	-43	16.80	17	-58	43	15.20	-29	19.20	59	-39
20	13	13.60	-38	16.80	18	-52	45	15.20	-26	19.20	61	-36
21	13	13.60	-38	16.80	18	-52	45	15.20	-26	19.20	61	-36

Maximum and minimum displacement at each stage

Stage no.	Displacement maximum m	elev.	minimum m	elev.	Stage description
1	0.000	14.00	-0.000	17.60	Change EI of wall to 100.00kN.m2/m run
2	0.000	12.00	-0.000	18.25	Apply surcharge no.1 at elev. 18.00
3	Wall displacements reset to zero				Change EI of wall to 30284kN.m2/m run
4	0.000	12.00	-0.000	19.20	Apply surcharge no.2 at elev. 18.00
5	0.001	19.20	0.000	19.20	Apply surcharge no.3 at elev. 19.00
6	0.005	19.20	0.000	19.20	Excav. to elev. 18.00 on PASSIVE side
7	No calculation at this stage				Install strut no.1 at elev. 18.50
8	0.005	19.20	0.000	19.20	Apply water pressure profile no.1
9	0.007	16.40	0.000	19.20	Excav. to elev. 15.00 on PASSIVE side
10	0.007	16.40	0.000	19.20	Change soil type 3 to soil type 5
11	0.007	16.40	0.000	19.20	Fill to elev. 15.40 on PASSIVE side
12	No calculation at this stage				Install strut no.3 at elev. 15.20
13	No calculation at this stage				Install strut no.2 at elev. 19.20
14	0.007	16.40	0.000	19.20	Remove strut no.1 at elev. 18.50
15	0.007	16.80	0.000	19.20	Apply surcharge no.4 at elev. 15.20
16	0.007	16.80	0.000	19.20	Apply water pressure profile no.3
17	0.008	16.80	0.000	19.20	Change soil type 2 to soil type 6
18	0.008	16.80	0.000	19.20	Change soil type 5 to soil type 6
19	0.007	16.80	0.000	19.20	Change soil type 4 to soil type 7
20	0.008	16.80	0.000	19.20	Change EI of wall to 21640kN.m2/m run
21	0.008	16.80	0.000	19.20	Apply water pressure profile no.3

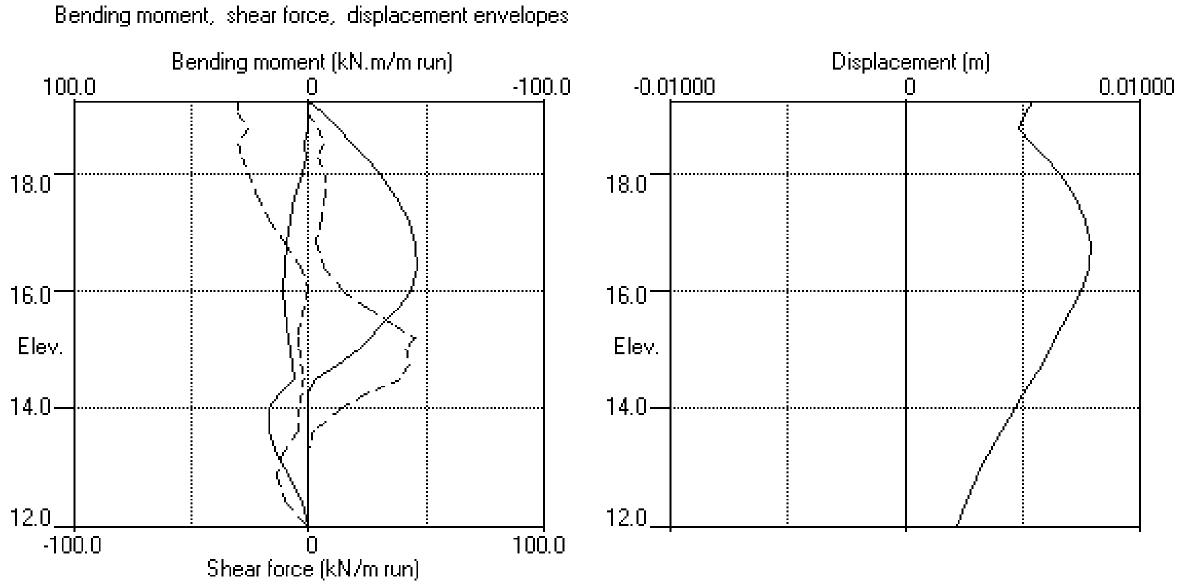
Calculated Bending Moments and Strut Forces have been multiplied by a factor of 1.35 to obtain values for structural design.

Strut forces at each stage (horizontal components)

Stage no.	Strut no. 1 at elev. 18.50 Calculated kN per m run	kN per strut	Factored kN per strut	Strut no. 2 at elev. 19.20 Calculated kN per m run	kN per strut	Factored kN per strut	Strut no. 3 at elev. 15.20 Calculated kN per m run	kN per strut	Factored kN per strut
8	0	1	1	---	---	---	---	---	---
9	35	174	235	---	---	---	---	---	---
10	36	182	246	---	---	---	---	---	---
11	36	182	245	---	---	---	---	---	---
14	---	---	---	28	28	37	12	12	16
15	---	---	---	29	29	39	slack	slack	slack
16	---	---	---	29	29	39	slack	slack	slack
17	---	---	---	30	30	41	7	7	10
18	---	---	---	30	30	40	14	14	18
19	---	---	---	29	29	39	27	27	37
20	---	---	---	26	26	36	35	35	47
21	---	---	---	26	26	36	35	35	47

* Indicates that the total force shown is the sum of the force in the strut plus a force applied at the same elevation which may represent temperature load or other forces which are part of the strut load. Force components are listed in the detailed results for individual stages.

Units: kN,m



APPENDIX D REINFORCEMENT CALCULATIONS

REFERENCE EC2 | Rev:

Bending and Axial Force to EN 1992-1-1:2004 (EC2) - Secant Wall — Circular Sections (Cast In-situ)

Pile section

	pile diameter	=	350	mm
	Pile spacing	=	550	mm
	design pile diameter h	=	330	mm
	Ac	=	85530	mm^2
4.4.1.3(4)	cover[1] c_{nom}	=	40	mm
	cage diameter d	=	218	mm
	ratio d/h	=	0.66	
	f_{ck}	=	28	MPa
	f_{yk}	=	500	MPa

k_2 = 50 mm

γ_c = 1.5 (This is adjusted by K_f=1.1 [2.4.2.5 (2)] to give 1.65)

γ_c = 1.65 α_{cc} = 1.0 [NA 3.1.6 (1)}

γ_s = 1.15 Already included in charts

Design Actions on pile

Actions N	=		kN
Factored Actions N	=		kN
Wallap shear	=	95	kN/m
Shear V_{Ed}	=	52.25	kN
Ult Shear V_{Ed}	=	52.25	kN
Wallap moment	=	68	kNm/m
Induced Moment M_i	=	37.4	kNm
Applied Moment M_{Ed}	=	0	kN
Σ Moments M	=	37	kN
Factored Ult M	=	37	kN

BM/SF factor 1.0

Using IstructE design charts for circular columns:-

$M/h^3 f_{ck}$ = 0.04 (also checked for M/h3=0.0 for zero vertical load)

Actions N $N/h^2 f_{ck}$ = 0.00

Factored Actions N $N/h^2 f_{ck}$ = 0.00

therefore from charts;

$\rho\ f_{yk} / f_{ck}$ = 0.15 **From charts**

ρ = $4A_{st} / \pi.h^2$

therefore, adopt greater of:

Area of main steel Ast = 718 mm^2 **or** Minimum steel area to BS EN 1536: 481 mm^2 for 350 mm dia. pile

main bar dia	=	16	mm	20	mm
no. main bars	=	6	no.	8	no.
helical dia	=	8	mm	8	mm
Area of main steel, A_{st}	=	1206	mm^2.		mm^2
Bar spacing (face to face)	=	98	mm		mm

REFERENCE | Rev:

EC2 **Shear to EN 1992-1-1:2004 (EC2) - Secant Wall** Circular Sections (Cast In-situ) using helical reinforcement

Pile section

	pile dia	=	350	mm		
	Pile spacing	=	550	mm		
	pile diameter dnom	=	330	mm		
	Ac	=	85530	mm^2		
4.4.1.3(4)	cover c_{nom}	=	40	mm	k_2 = 50 mm	[NA.1 4.4.1.3 (4)]
	main bar dia	=	16	mm		
	no. main bars	=	6	no.		
	helical dia	=	8	mm		
	d	=	229	mm	γ_c = 1.5 (This is adjusted by K_f=1.1 [2.4.2.5 (2)] to give 1.65)	
	f_{ck}	=	28	MPa	γ_c = 1.65 α_{cc} = 0.85	[NA.1 3.1.6 (1)}
	f_{yk}	=	500	MPa	γ_s = 1.15	
	Wallap shear	=	95	kN/m		
		=	52.25	kN	SF factor 1.0	
	Ult V_{Ed}	=	52.25	kN		
	Actions N	=		kN		
	factored actions N_{Ed}	=		kN		

6.2.2 Check requirement for shear reinforcement

$V_{Rd,c}$ = $[C_{Rd,c}k(100\rho_1 f_{ck})^{1/3}+k_1\sigma_{cp}]b_w d$

with minimum = $(v_{min}+k_1\sigma_{cp})b_w d$

v_{min} = $0.035k^{3/2}f_{ck}^{1/2}$

0.49809039

CRd,c	=	0.18 / γc	0.11	
k	=	$1+(200/d)^{1/2}$	1.93	<=2.0
ρ_1	=	$A_{sl}/b_w d$	0.01	<=0.02
σ_{cp}	=	N_{ed}/A_c	0	< $0.2f_{cd}$
k_1	=	0.15		[NA.1 6.2.2(1)]

$V_{Rd,c}$ = **38** kN

Is $V_{Rd,c} > V_{Ed}$ => **NO** Action: ***Design of shear reinforcement required***

6.2.3 Design Shear Reinforcement

Check concrete strut capacity at Cot θ = 2.5 :-

6.2.3 (3) exp 6.9

$V_{Rd,max}$ = $\alpha_{cw}.b_w.z.v_1.f_{cd}$ / (Cotθ+tanθ) (6.9)

$V_{Rd,max}$ = **180** **kN**

cot θ	=	2.5		
tan θ	=	0.4		
α_{cw}	=	1		[NA.1 6.2.3(3)]
z	=	0.9d	206	mm
v_1	=	0.6 (1-(fck/250)	0.53	[6.6N]

Is $V_{Rd,c} > V_{Ed}$ => **YES** Action: ***Calculate link spacing***

Calculation for strut inclination:-

θ = $0.5.\sin^{-1}[(6.54*V_{Ed})/(b_w.d.(1-f_{ck}/250).f_{ck})$

θ = NA rad cot θ = 2.5 > 1.0

Calculate shear reinforcement spacing after Turmo et al (2008);-

$V_{Rd,s}$ = $z.\cot\theta.(A_\Phi/0.5s).f_{ywd}.0.85$ A_{sw} = 50.3 mm^2

s = $2.([z.\cot\theta.A_\Phi.fywd.0.85]/V_{Rd,s})$ f_{ywd} = 435 MPa

= **367** mm

Check maximum shear link spacing:-

is $s_{l,max}$ > 0.75d **YES**

Provide **8** mm helical at nominal pitch **170** mm

Turo, J, *et al*. Shear truss analogy for concrete members of solid and hollow circular cross section. **Eng. Struc.** (2008)

MICHAEL CHESTER & PARTNERS Consulting Civil and Structural Engineers
8 Hale Lane London NW7 3NX tel 020 8959 9119 fax 020 8959 9662 mail@michaelchester.co.uk

APPENDIX C

66 FITZJOHN'S AVENUE, LONDON NW3

GEOTECHNICAL REPORT BY DONALDSON ASSOCIATES

DONALDSON
ASSOCIATES
a COWI company

Duncan Mercer
Michael Chester & Partners LLP
8 Hale Lane
London NW7 3NX

ADDRESS Donaldson Associates Limited
Bevis Marks House
24 Bevis Marks
London
EC3A 7JB

TEL 020 7407 0973
WWW donaldsonassociates.com

DATE 3 June 2016

REF HISK
PROJECT NO EL426

Dear Duncan,

66 Fitzjohn's Avenue

This report assesses the potential ground movement and building damage, due to construction of a basement at the site.

The site is on Fitzjohn's Avenue, south of Lyndhurst Road, and covers the plot of land behind No.64. There is currently a two storey semi-detached building on the site (with no basement) and this is to be demolished and replaced with a new three storey building with a single storey basement.

A site investigation has been carried out and consisted of one 15m deep cable percussion borehole and two window samples. The ground consists of the Claygate Beds (clayey) over London Clay with the Claygate member extending to about 3m depth. Standpipes installed in September showed the water level at the time to be about 900mm above structural slab level.

The basement will be formed of a propped secant piled wall to form a cutoff so that the water within the excavation of 4.5m can be pumped out.

62/64 Fitzjohn's Avenue is around 3m and 14 Akenside Road is around 10m from the excavation.

Secant wall installation

Very little movement is to be expected when installing a secant wall in clay using modern plant. Limited data has been published in CIRIA C580[1] from prior to the 1990's and is available to provide an initial estimate. This is based on

[1] CIRIA C580 *"Embedded retaining walls – guidance for economic design", London 2003, see figures*

TRL Reports PR23[2] and R172[3]. Of particular interest is that 4 out of 5 of these piled walls were installed into a London geology sequence of made ground, claygate beds/head (firm clay) or terrace gravels over London clay.

Assuming a wall depth of around 7m, movements based on C580 of 2-3mm vertically and 2-4mm horizontally may be expected at the façades of 62/64 Fitzjohn's Avenue. At 14 Akenside Road up to 2mm vertically and horizontally may be expected at the facade.

Settlement due to basement excavation

Ground movement curves have been published in CIRIA C580[4] based on empirical correlations of case history field measurements. The ground movement curves are shown in the figures. These ground movements have been derived from monitored surface movements due to the excavation in front of bored piles, diaphragm and sheet pile walls wholly embedded in stiff clay. In 16 of 17 case studies walls were installed into a London geology sequence of made ground, claygate beds/head (firm clay) or terrace gravels over London clay and so are relevant to the current site. The ground movements are expressed in terms of percentage of maximum excavation depth, here 4.5m.

62/64 Fitzjohn's Avenue is around 3m from the excavation. Movements based on this of 2-4mm vertically and 4-5mm horizontally may be expected at the facades.

14 Akenside Road is around 10m from the excavation. Movements based on this of up to 2mm vertically and 1-3mm horizontally may be expected at the facades.

Heave due to overburden removal

Settlements calculated by reference to C580 include an element caused by excavation heave. Using an adjusted elasticity method (BSEN 1997:2005 Geotechnical Design Part 1 General Rules Appendix F) and conservatively taking cu=65kPa as the soil strength over the heave bulb. Following the C580 recommendation, Eu=65 x 425kPa, the initial heave at the centre of the base

---

[2] TRL PR23 "*Behaviour during construction of a propped contiguous bored pile wall in stiff clay at Rayleigh Weir*", 1994

[3] TRL R172, *"Ground movements caused by different embedded retaining wall construction techniques"*, 1995

[4] CIRIA C580 *"Embedded retaining walls – guidance for economic design",* London 2003, see figures

of the excavation can be estimated by treating the excavation as a negative load. The base of the excavation will heave around 20mm as overburden is removed. The effect of heave movements on adjacent buildings during construction will be limited by the wall depth, stiffness and propping. In the longer term, slab construction and the re-imposition of building loading will limit heave to negligible levels.

Building damage assessment

An initial assessment of building damage can be made using C580 empirical estimates of ground movement.

BUILDING	v (mm)	h (mm)	Deflection ratio, M (%)	Horizontal strain, εh (%)	DAMAGE CATEGORY
62/64 FA	4-7	6-9	~0	0.05	0/1
14 AR	0-4	1-5	~0	0.05	0/1

Conclusion

Basement construction has the potential to cause ground movements during wall installation, excavation and in the longer term. Longer term ground movements will be limited by wall and basement design.

Ground movements during wall installation and excavation have been empirically derived based on the construction methodology in the BIA and indicated category 0/1 damage.

14 Akenside Road is around 10m from the excavation and at low risk of damage. No further assessment is proposed.

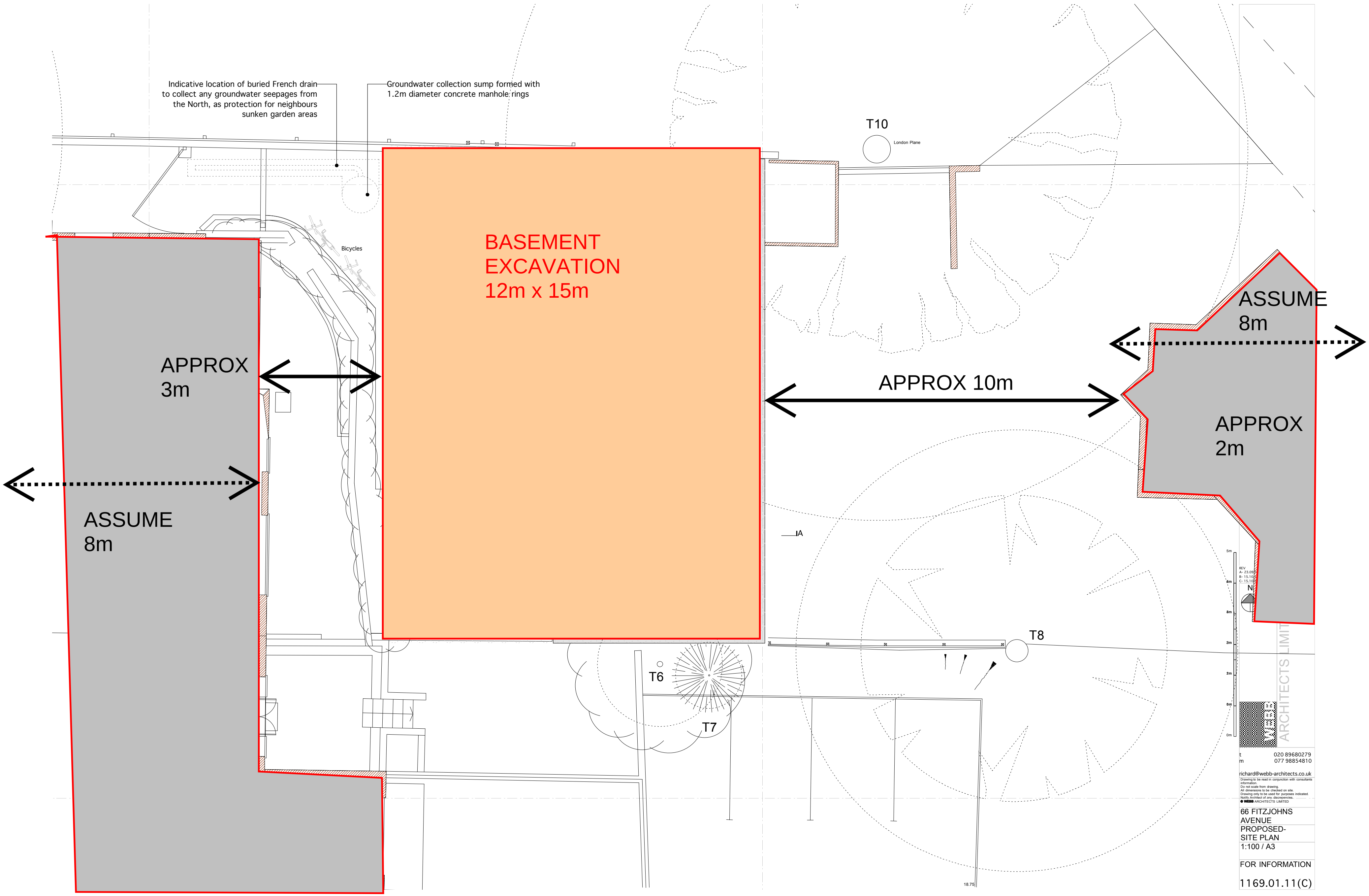
62/64 Fitzjohn's Avenue is around 3m from the excavation and the initial screening suggests a low risk of damage. However, given its proximity to the excavation, it is suggested that the BIA construction methodology used for the assessment is confirmed to still be the case when basement design and sequencing is finalised. It is likely that a condition survey and some façade monitoring will be required.

I hope that this report answers the questions raised by the BIA review.

Yours sincerely,

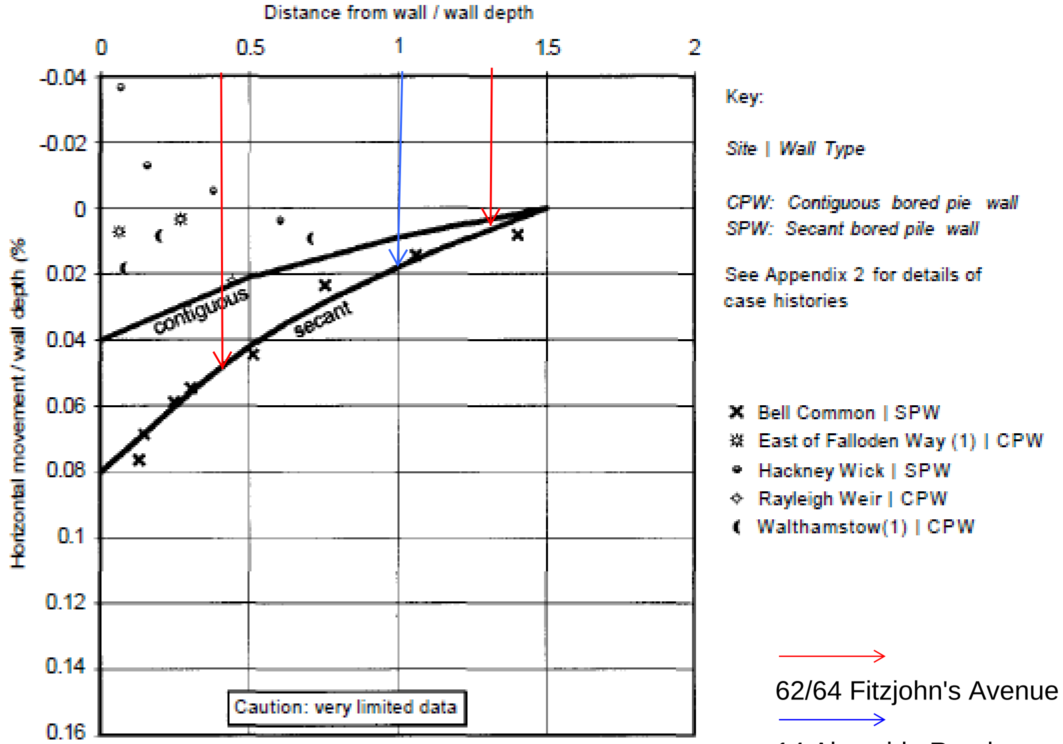
Hilary Skinner

SITE PLAN

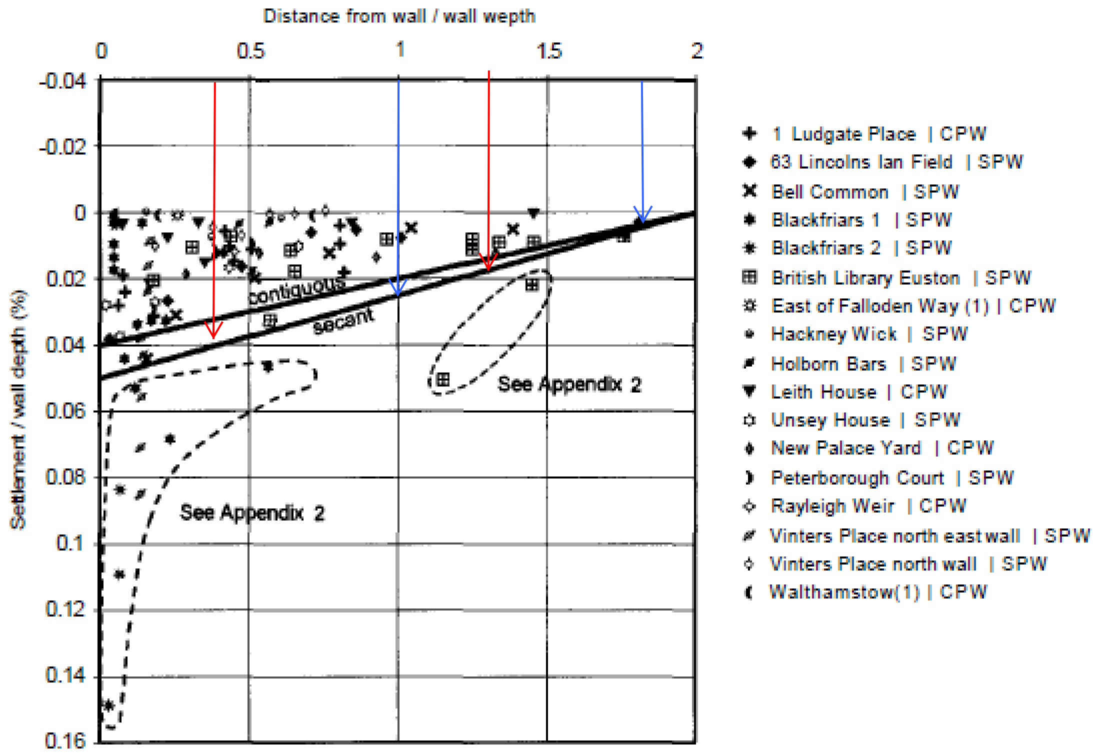


Indicative location of buried French drain to collect any groundwater seepages from the North, as protection for neighbours sunken garden areas
Groundwater collection sump formed with 1.2m diameter concrete manhole rings
Bicycles
BASEMENT EXCAVATION 12m x 15m
T10
London Plane
APPROX 3m
ASSUME 8m
APPROX 10m
ASSUME 8m
APPROX 2m
T8
T6
T7
t 020 89680279
m 077 98854810
richard@webb-architects.co.uk
Drawing to be read in conjunction with consultants information.
Do not scale from drawing.
All dimensions to be checked on site.
Drawing only to be used for purposes indicated.
Notify Architect of any discrepencies.
© WEBB ARCHITECTS LIMITED
66 FITZJOHNS AVENUE
PROPOSED- SITE PLAN
1:100 / A3
FOR INFORMATION
1169.01.11(C)

Figures from CIRIA C580 "Embedded retaining walls – guidance for economic design", London 2003



(a) Horizontal movements



(b) Vertical movements

Figure 2.8 *Ground surface movements due to bored pile wall installation in stiff clay*

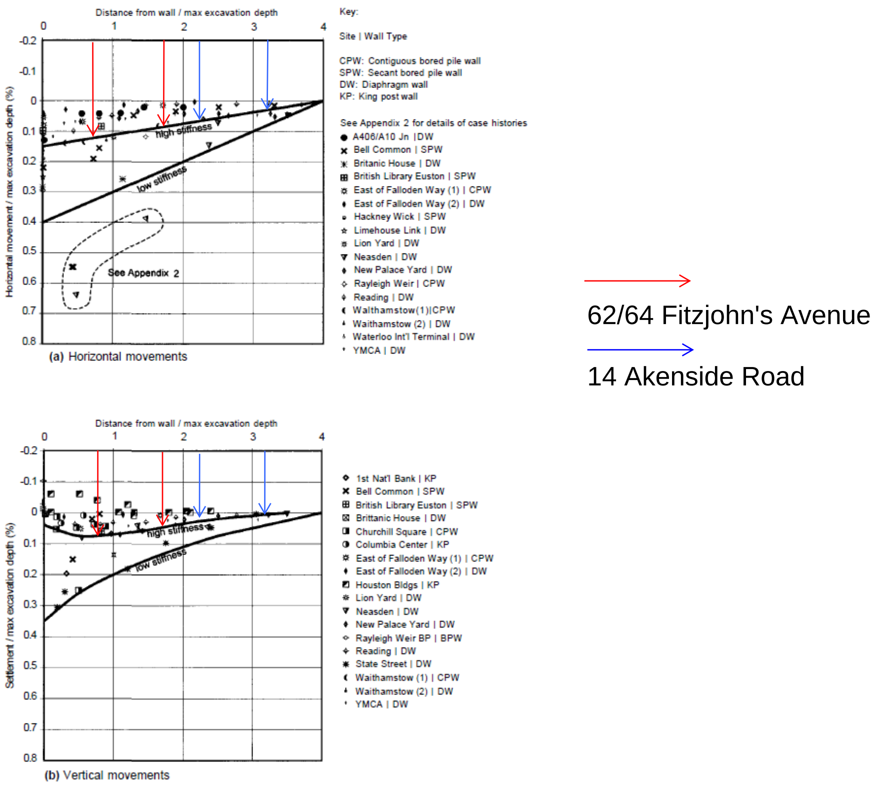
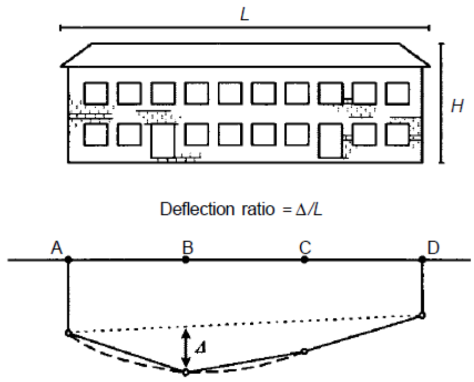
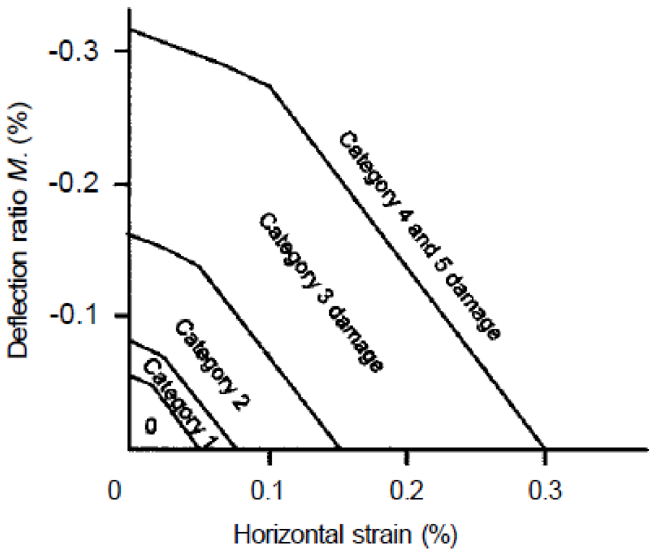


Figure 2.11 *Ground surface movements due to excavation in front of wall in stiff clay*



(a) Definition of deflection ratio.



(c) Relationship between damage category and deflection ratio and horizontal tensile strain for hogging for (L/H) = 1.0 (after Burland, 2001)

MICHAEL CHESTER & PARTNERS Consulting Civil and Structural Engineers
8 Hale Lane London NW7 3NX tel 020 8959 9119 fax 020 8959 9662 mail@michaelchester.co.uk

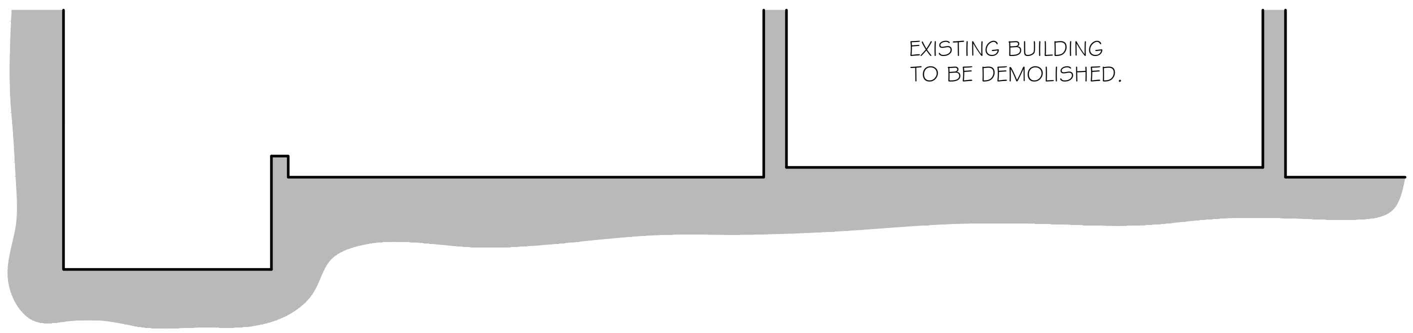
APPENDIX D

66 FITZJOHN'S AVENUE, LONDON NW3

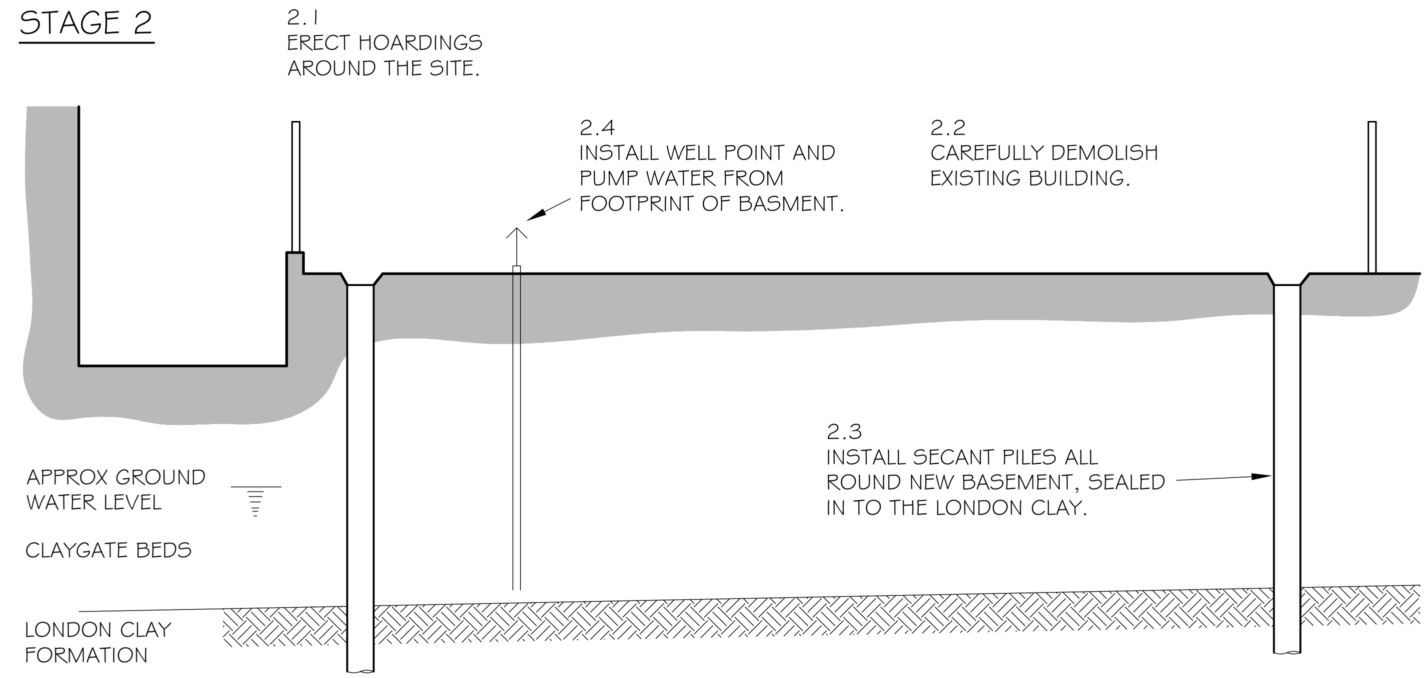
DRAWING NUMBER 15094/SK02revA BY MICHAEL CHESTER & PARTNERS

STAGE 1

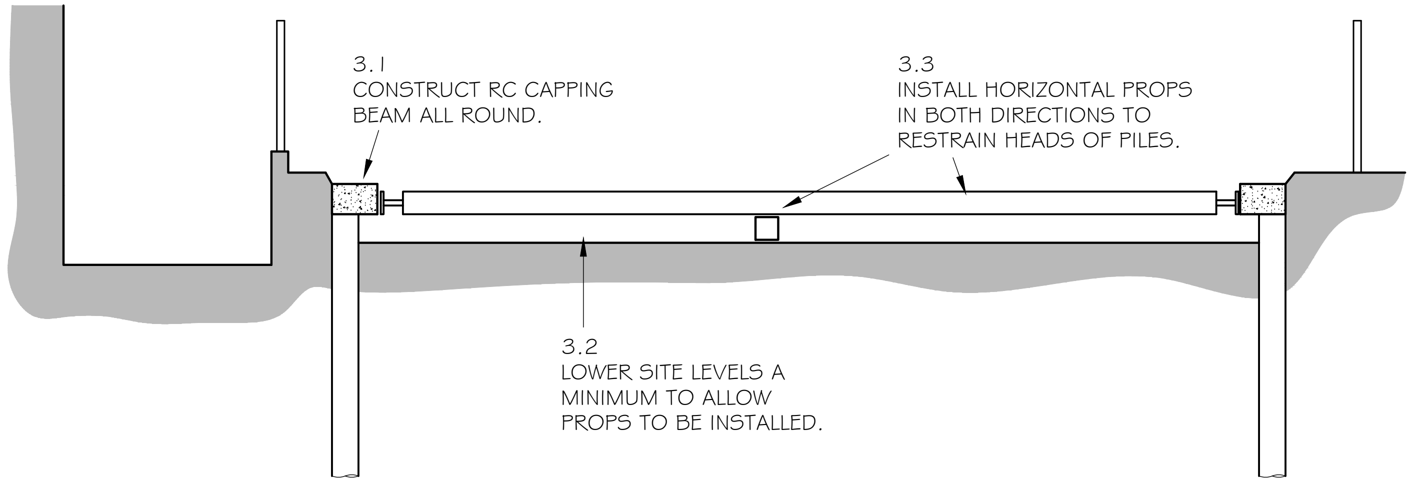
EXISTING.



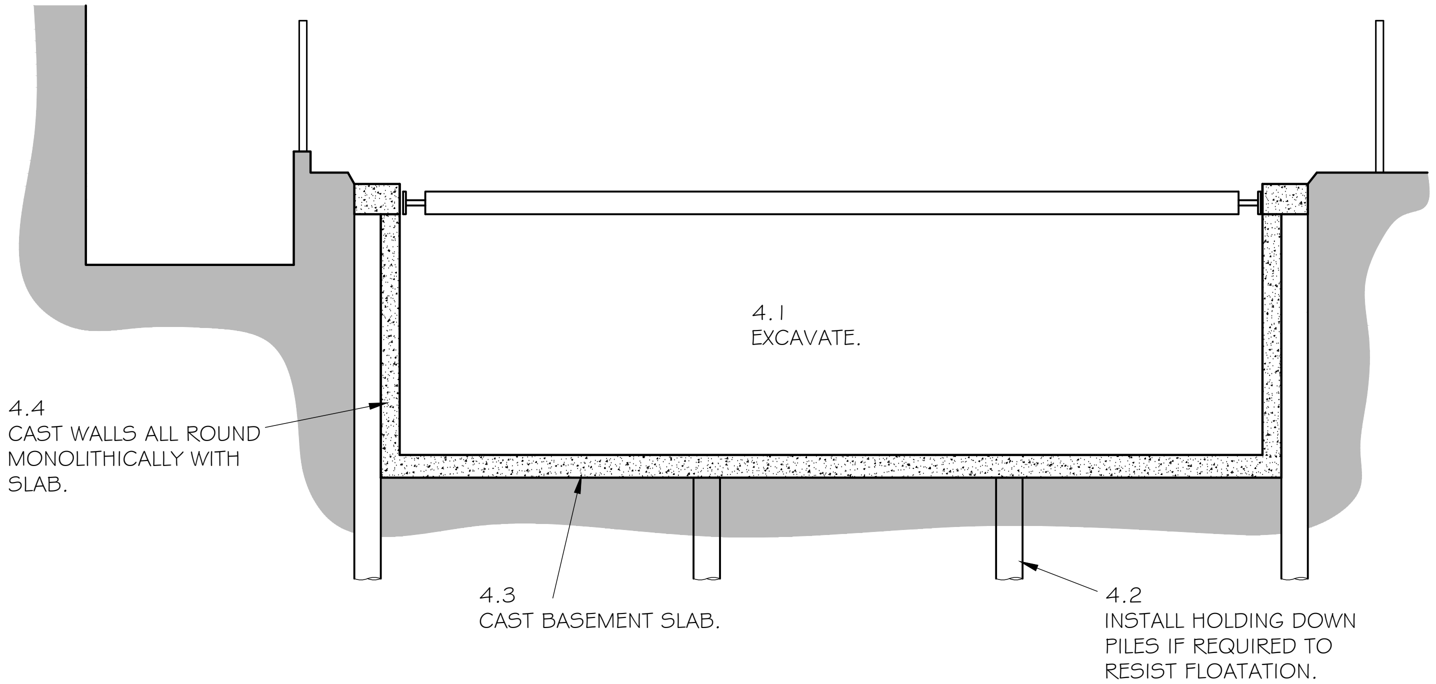
STAGE 2



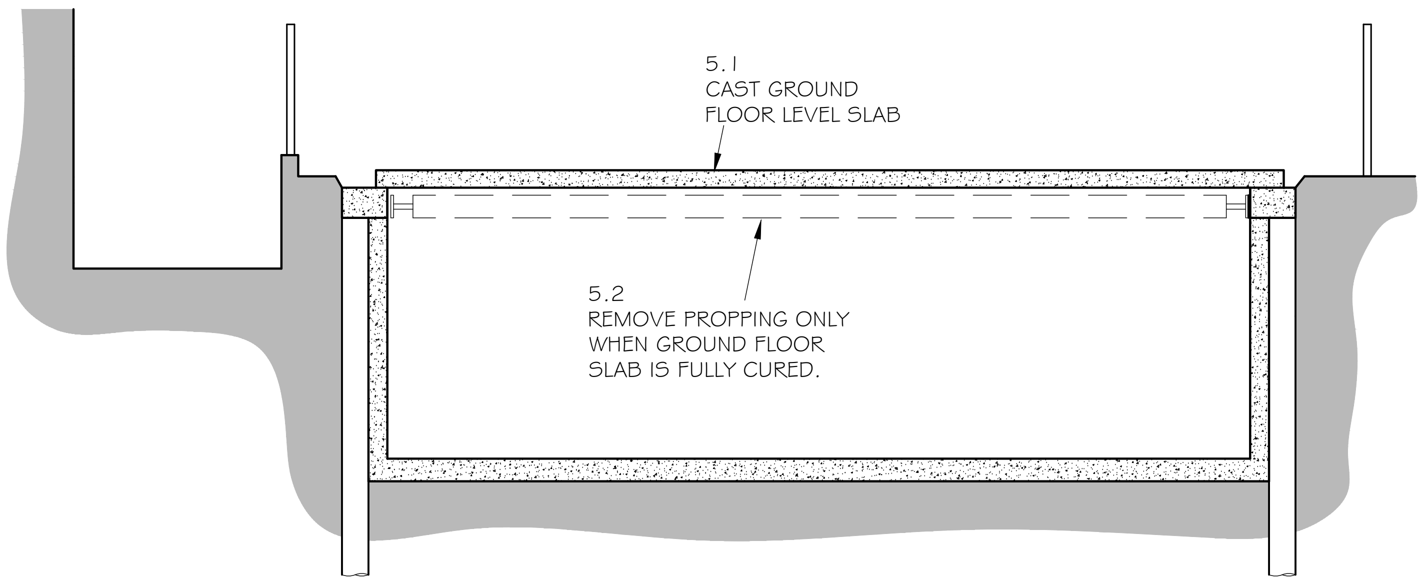
STAGE 3



STAGE 4



STAGE 5



Rev	Date	Alteration
A	SEPT 15	NOTES ADDED.

MICHAEL CHESTER & PARTNERS
Consulting Civil and Structural Engineers
8 Hale Lane London NW7 3NX tel 020 8959 9119 fax 020 8959 9662

ASSUMED SEQUENCE OF CONSTRUCTION

Date JULY 15
Drawn DM
Scale nts
Drg No 15094/SK02
Rev A

Project
66 FITZJOHNS AVENUE
LONDON NW3

PRELIMINARY

A3